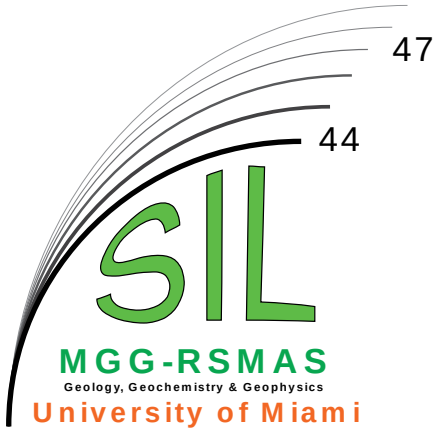
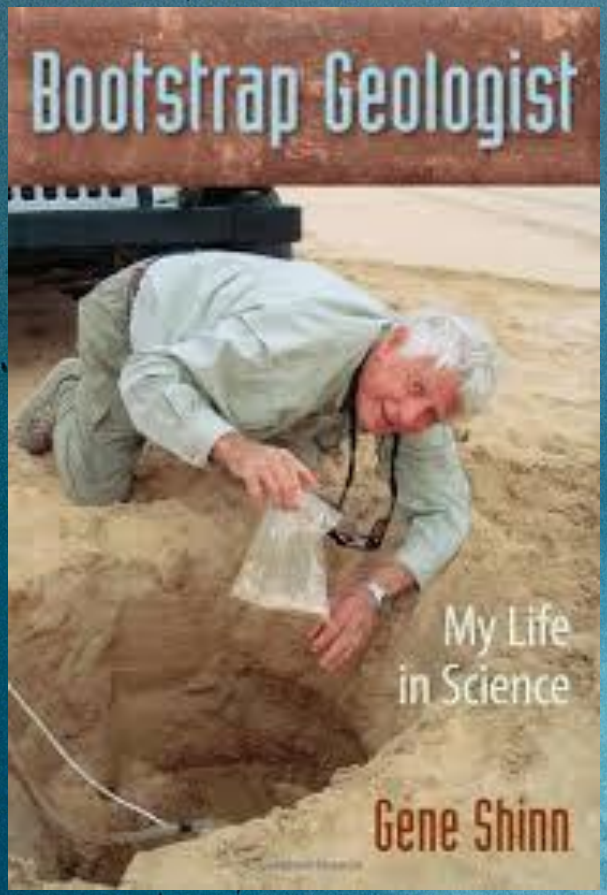
Is Dust the Answer to Life, the Bahamas, and Everything? No Fish Story

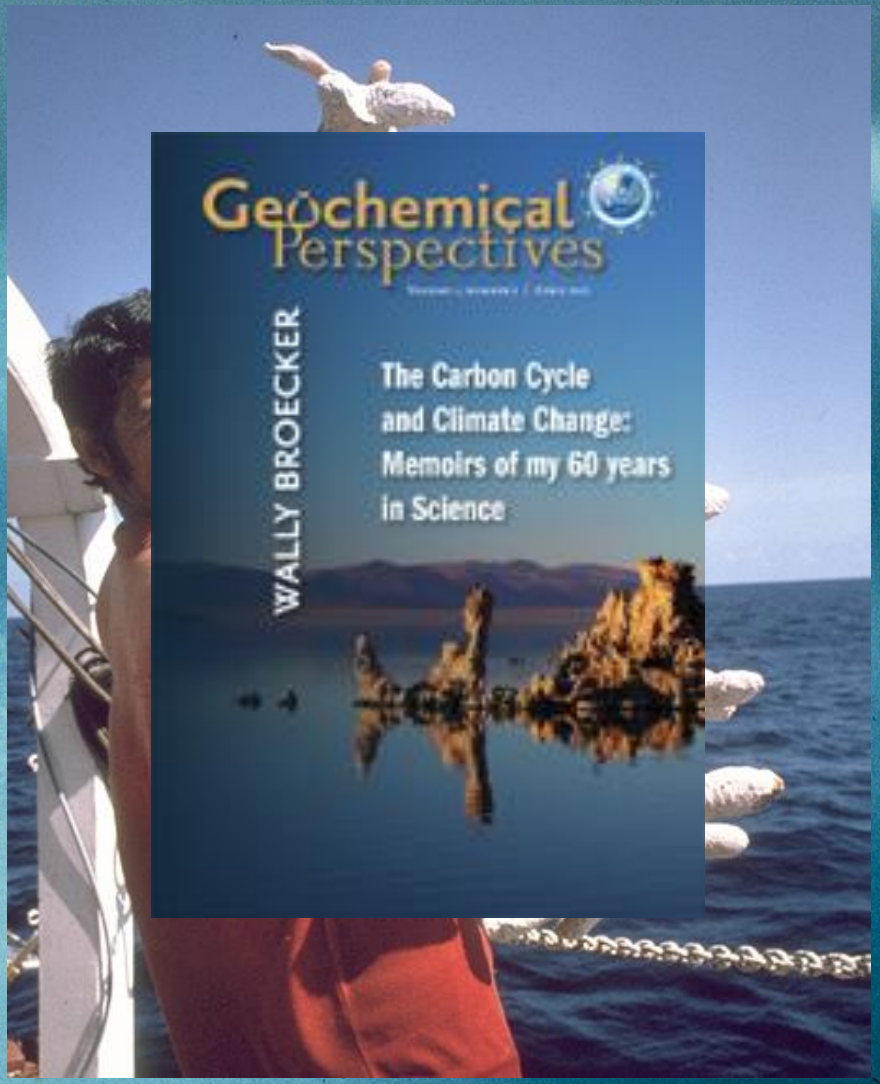
Peter K. Swart
Department of Marine Geosciences

Special Thanks To:
Amanda M. Oehlert, Greta J. Mackenzie, John J. Reijmer, Gregor P. Eberli
Mara Diaz, Jim Klaus, Ali Pourmand, Tim Lyons
Amy Clement
Bob Ginsburg
Gene Shinn



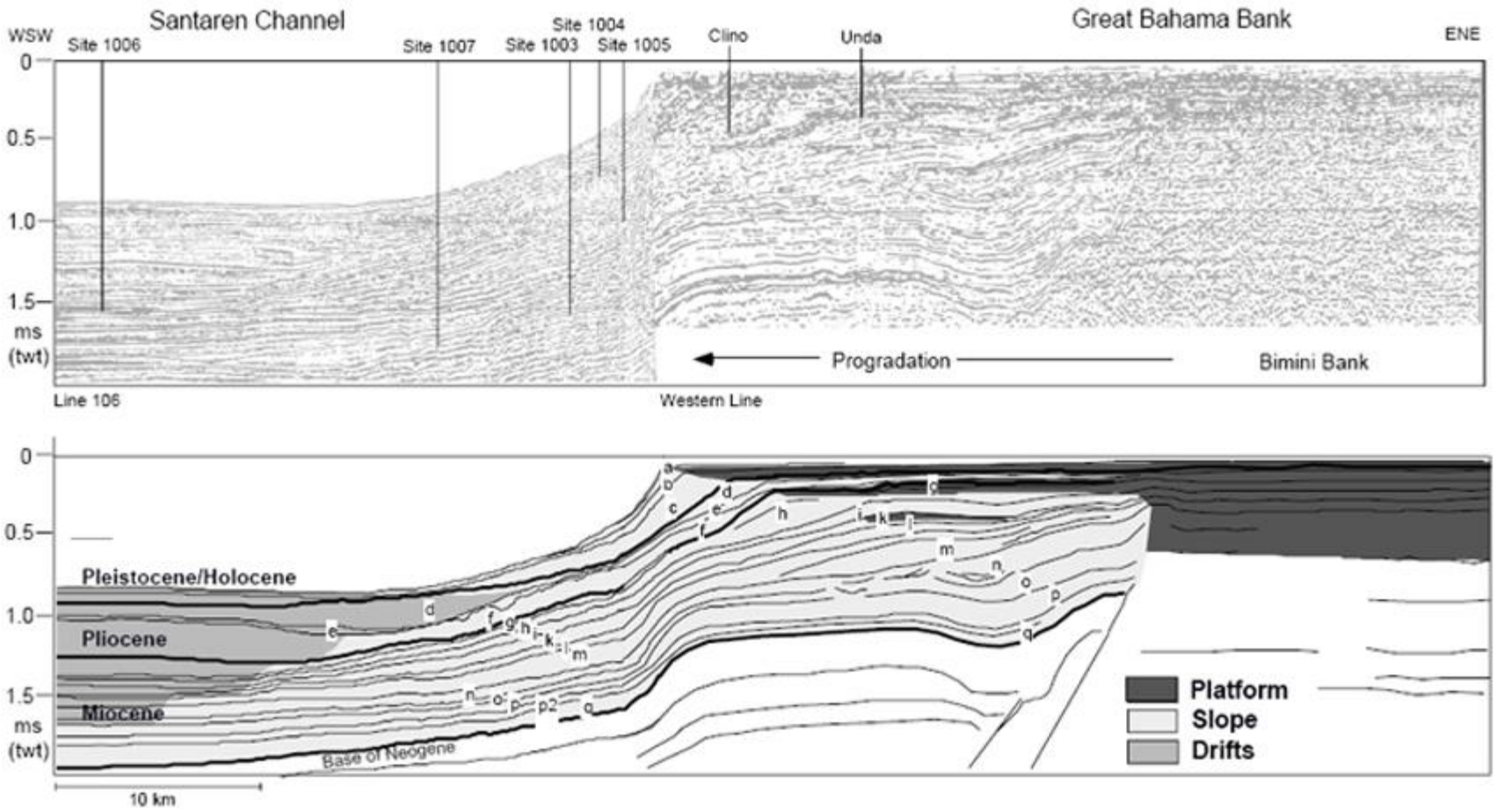
Geotopics 2014


Bootstrap Geologist
My Life
in Science
Gene Shinn


Geochemical
Perspectives
WALLY BROECKER
The Carbon Cycle
and Climate Change:
Memoirs of my 60 years
in Science

The Bahamas

1. World's largest carbonate platform
2. Only modern platform where there is significant amount of non-biogenic precipitation
3. ~ 100 Myrs Old
4. 1000s of meter of shallow water carbonates
5. Exists in an oligotrophic setting



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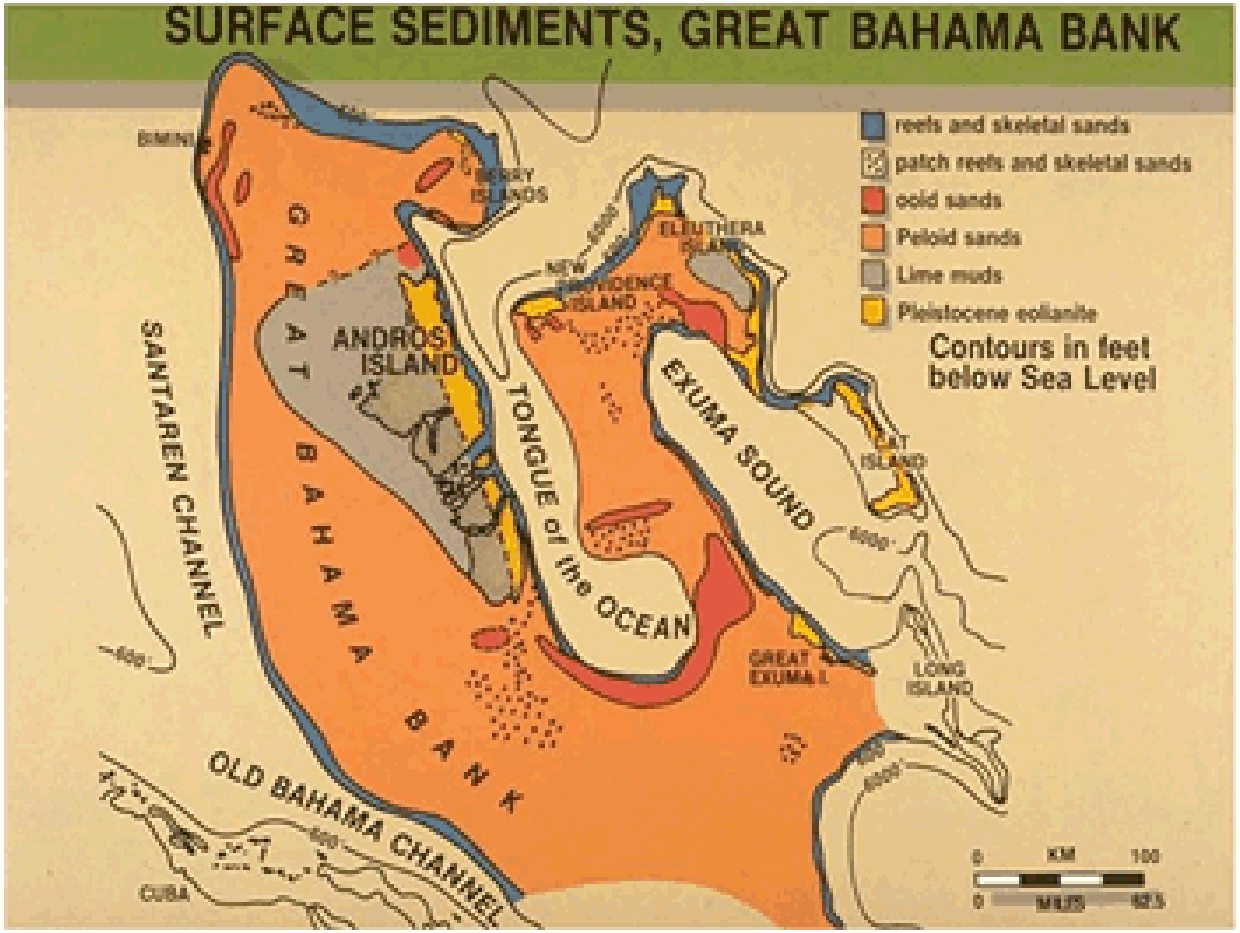

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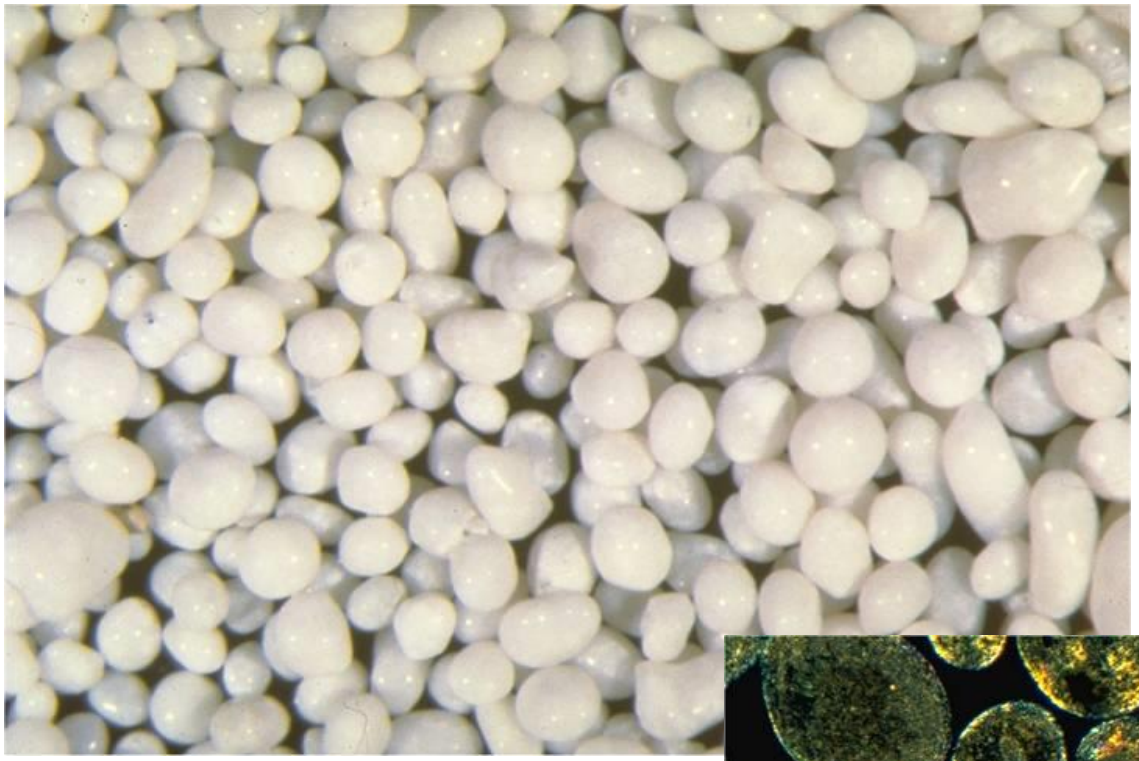
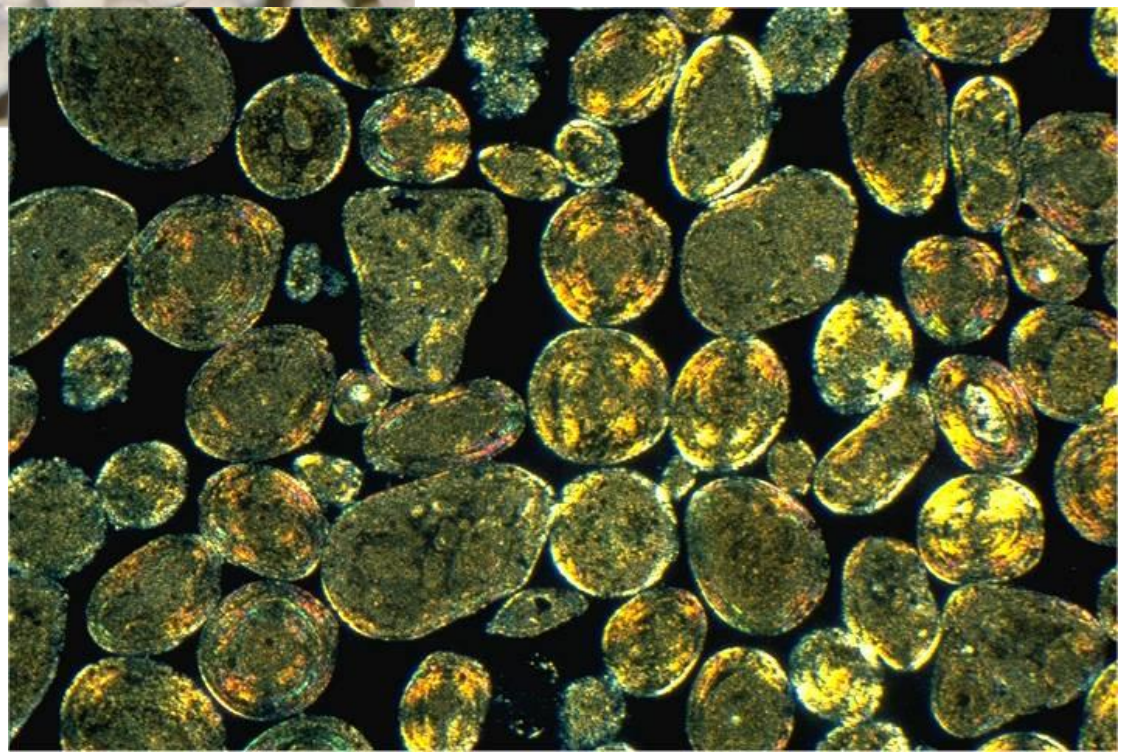


SEPM Photo CD Marine Carbonates



SEPM Photo CD Marine Carbonates


SEPM Photo CD Marine Carbonates

The Gods of the Carbonate-Mud Argument

BLACK, M., 1933, The precipitation of calcium carbonate on the Bahama Bank: Geological Magazine, v. 70, p. 455-466.

SMITH, C., L, 1940, The Great Bahama Bank:1 General hydrographic and chemical factors, 2. Calcium carbonate precipitation: Journal of Marine Resources, v. 3, p. 147-189.

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University of Miami

Calcium Carbonate Precipitation on the Bahama Banks[1]

WALLACE S. BROECKER

JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 45, NO. 4, P. 763–786
FIGS. 1–10, DECEMBER 1975

LIME MUD DEPOSITION AND CALCAREOUS ALGAE IN THE BIGHT OF ABACO, BAHAMAS: A BUDGET[1]

A. CONRAD NEUMANN AND LYNTON S. LAND

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 89, NO. C3, PAGES 3604-3614, MAY 20, 1984

THE CARBONATE CHEMISTRY OF GRAND BAHAMA BANK WATERS: AFTER 18 YEARS ANOTHER LOOK

John W. Morse

Department of Oceanography, Texas A&M University

Frank J. Millero, Valerie Thurmond, Elissa Brown, and H.G. Ostlund

Rosenstiel School of Marine and Atmospheric Science, University of Miami

PETER K. SWA...

$CaCO_3$ precipitation kinetics in waters from the Great Bahama Bank: Implications for the relationship between Bank hydrochemistry and whitings

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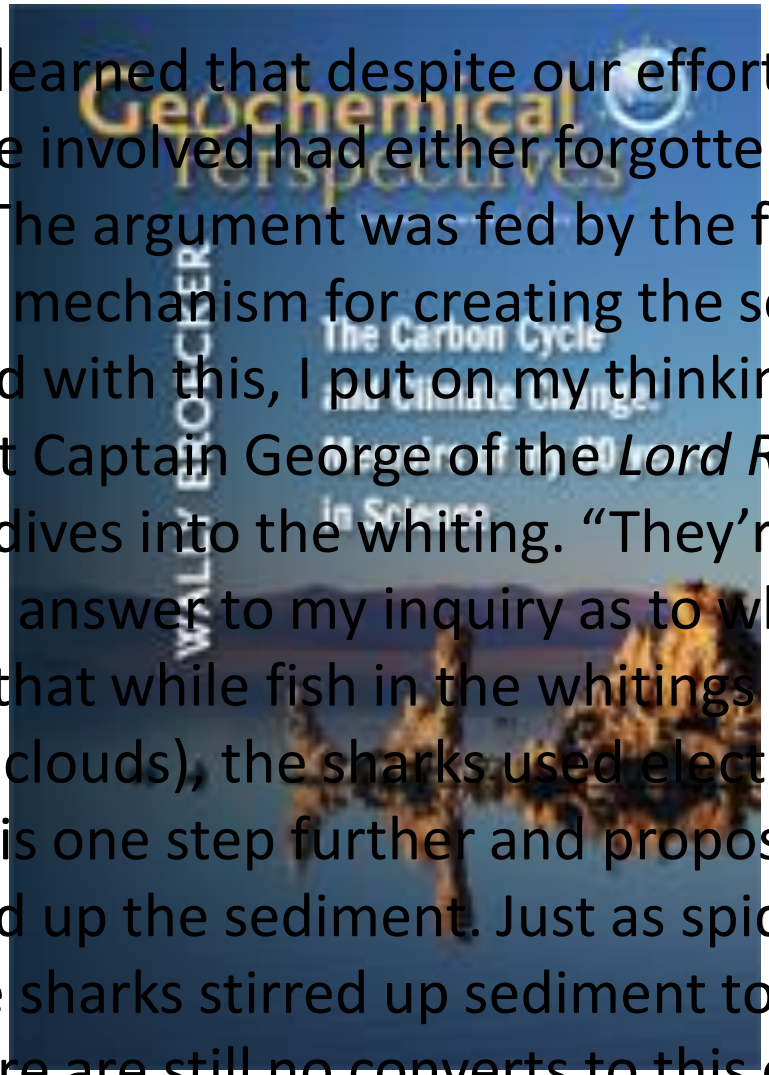
Stirred Up Hypothesis

- No Change in alkalinity between inside and outside.
  - Such a change would be expected if direct precipitation was taking place.
- Age of the whitings was old rather than young
- Their suggestion was that the whitings were caused by fish, although no attempt was made to see if there were any fish present.

- “Decades later, I learned that despite our efforts, the debate still raged. The people involved had either forgotten or disregarded our publication. The argument was fed by the failure to come up with a believable mechanism for creating the sediment suspension. Faced with this, I put on my thinking cap. I remembered that Captain George of the *Lord Raleigh* had forbidden scuba dives into the whiting. “They’re loaded with lemon sharks.” In answer to my inquiry as to why they might be there, I was told that while fish in the whitings were blind (as are airplane pilots in clouds), the sharks used electric sensors to locate the fish. I took this one step further and proposed that it was the sharks that stirred up the sediment. Just as spiders spin webs to catch insects, the sharks stirred up sediment to catch fish but, as far as I know, there are still no converts to this explanation.”



Broecker, 2011

PERSPECTIVES:

WHITINGS, A SEDIMENTOLOGIC DILEMMA[1]

EUGENE A. SHINN,* RANDOLPH P. STEINEN,† BARBARA H. LIDZ* A
*U.S. Geological Survey, Fisher Island Station, Miami Beach, Florid
†Department of Geology, University of Connecticut, Storrs, Connectic
‡Marine Geology and Geophysics, Rosenstiel School of Marine and Atmos
4600 Rickenbacker Causeway, Miami, Florida 33149

COMMENT ON THE ORIGIN OF ARAGONITE NEEDLE MUD: A PICTURE IS WORTH A THOUSAND WORDS[1]

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Department of Paleobiology
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560
AND
MELA REID
rine and Atmospheric Science
ity of Miami
backer Causeway
Florida 33149

HINN, E.A., STEINEN, R.P., LIDZ, B.H., and HALLEY, R.B., 985, Bahamian Whitings-No Fish Story: American Assoc. of etrol. Geol. Bull., v. 69, p. 307.

STEINEN, R.P., SWART, P.K., SHINN, E.A., and LIDZ, B., 1988, Bahamian lime mud: The Algae Didn't do it: Geological Society of America Abstracts with Program, v. 20, p. A209.

L. L. Robbins
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P. L. Blackwelder
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PERSPECTIVES:

WHITINGS, A SEDIMENTOLOGIC DILEMMA[1]

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†Department of Geology, University of Connecticut, Storrs, Connecticut 06268
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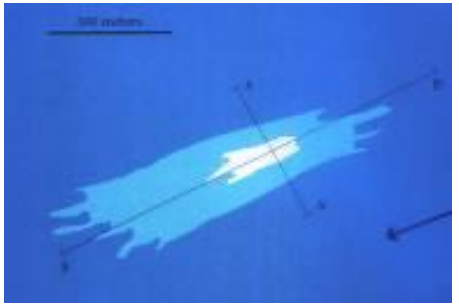
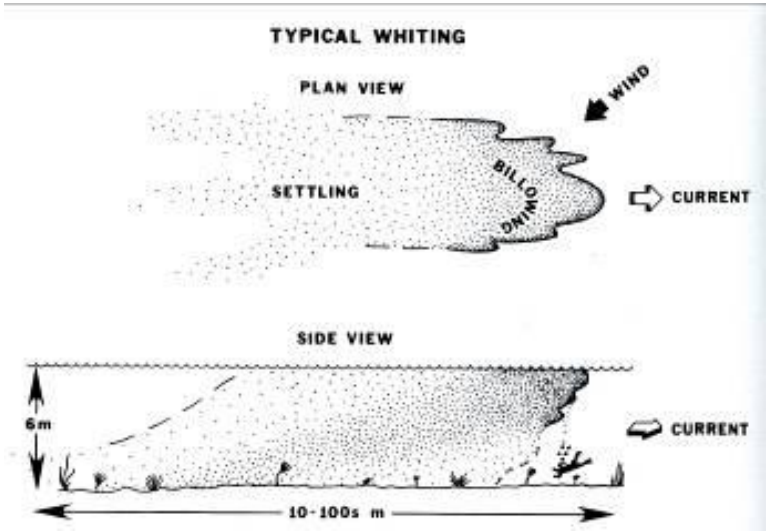
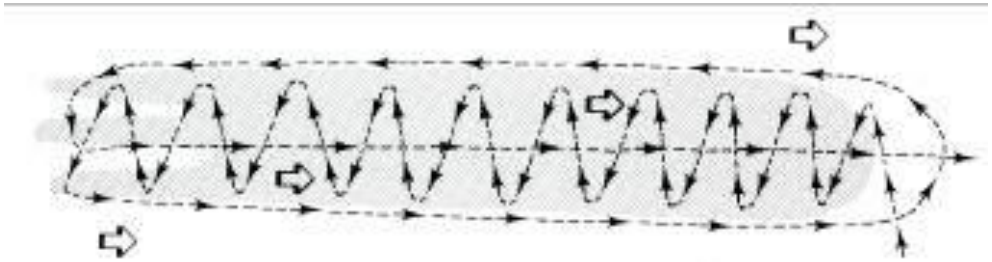
4600 Rickenbacker Causeway, Miami, Florida 33149



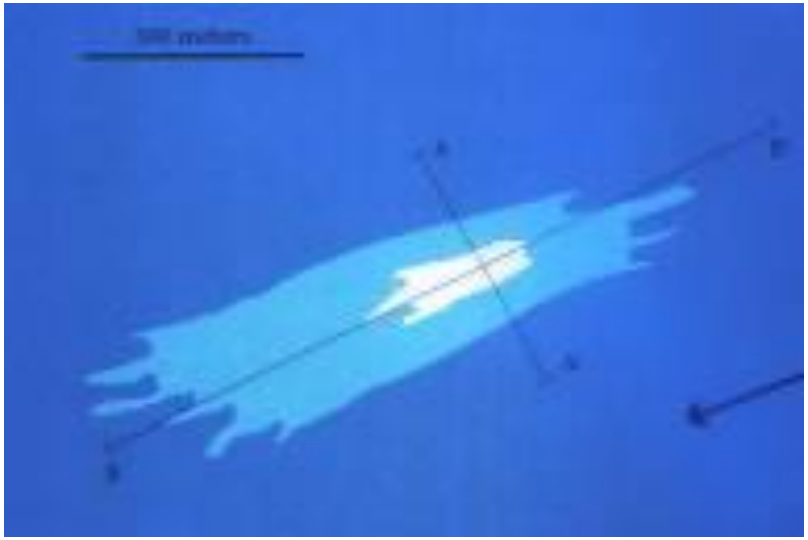




- Measured the amount of precipitation arising from Whitings (34 g/m^2/hr)
- These rates would be sufficient to deplete the whiting and therefore they must be being replenished
- No evidence of fish
- Geochemical data (C-14 and stable isotopic data) support that some component is directly precipitated

Bootleg Cruises

- Between 1988-1992
  - Participated on cruises with Lisa Robbins in which we measured alkalinity changes within and outside whitings.
  - The whiting was much larger than just the intense white area.



Biochemical and ultrastructural evidence for the origin of whitings: A biologically induced calcium carbonate precipitation mechanism

L. L. Robbins
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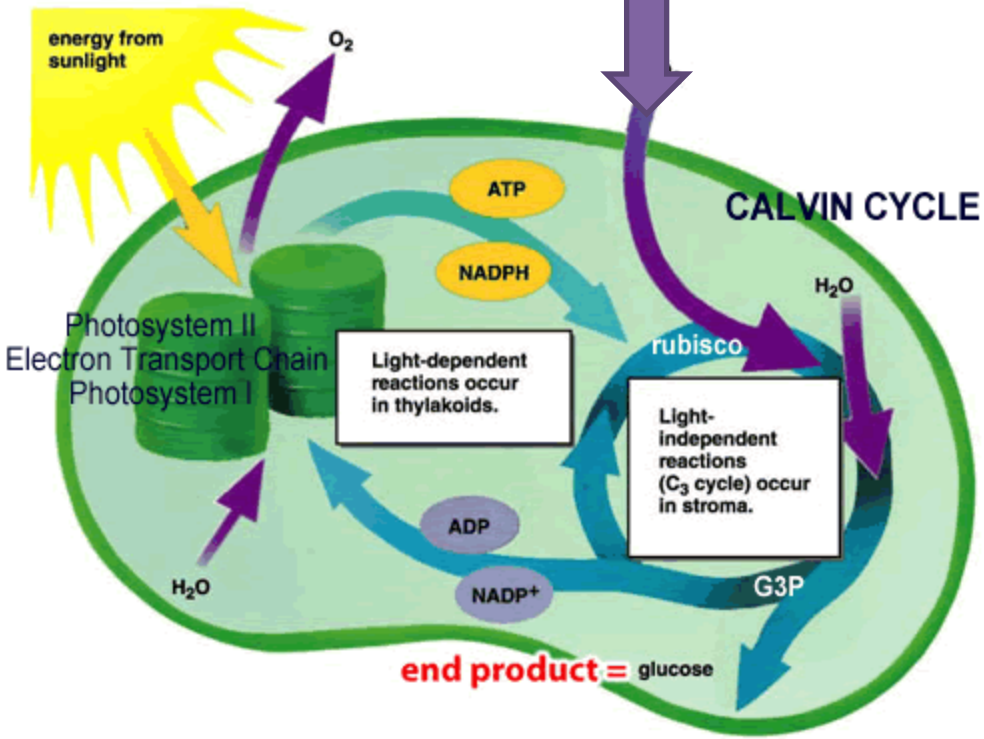
P. L. Blackwelder
Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway
Miami, Florida 33149

1992

http://protist.i.hosei.ac.jp/pdb/images/Prokaryotes/Cyanobacteria/Cyanobacteria3.html

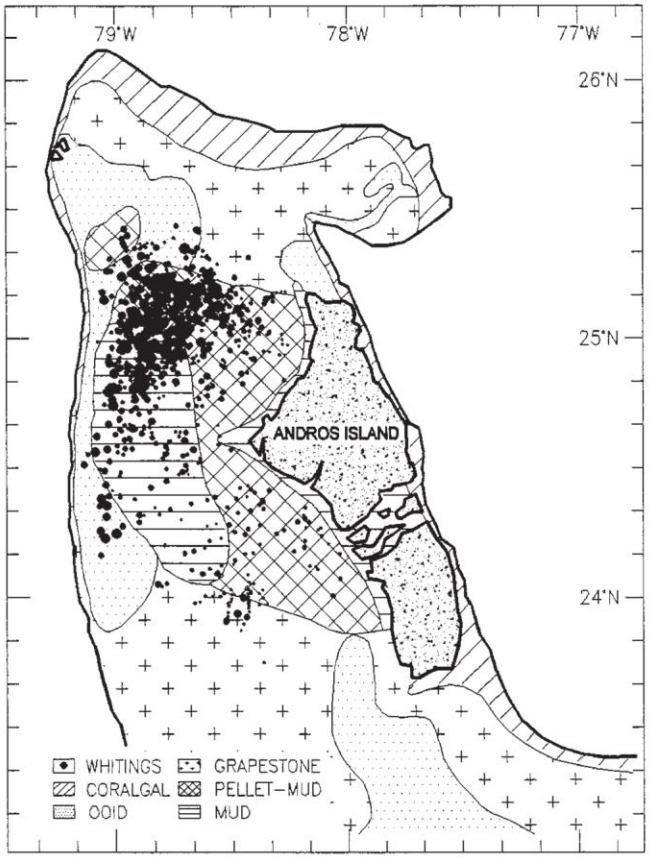
$$Ca^{2+} + 2HCO_3^- = CaCO_3 + CO_2 + H_2O$$

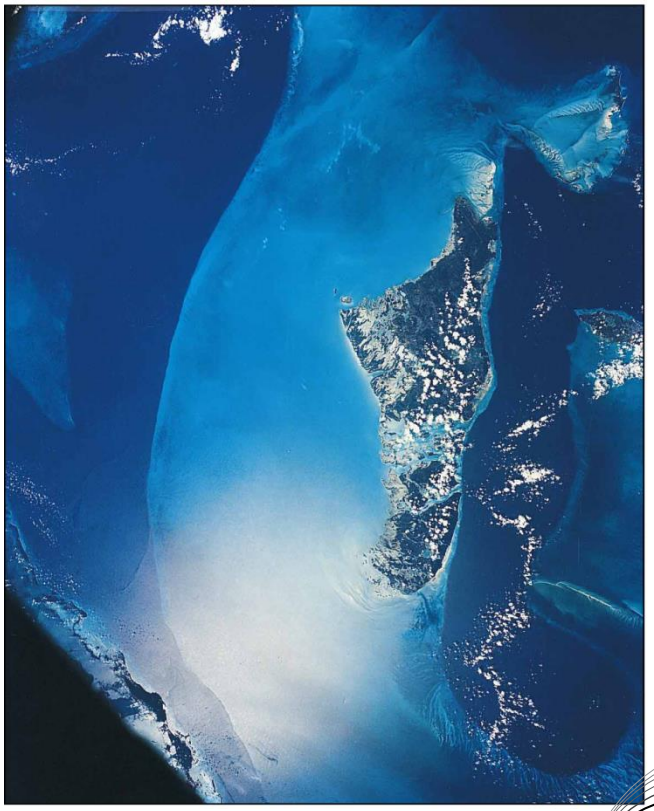


http://www.biologycorner.com/APbiology/cellular/notes_photosynthesis1.html

Temporal and spatial distribution of whitings on Great Bahama Bank and a new lime mud budget

L. L. Robbins*
Y. Tao
Department of Geology, University of South Florida, Tampa, Florida 33620
C. A. Evans Lockheed, Engineering and Science Program, 2400 NASA Road 1, P.O. Box 58561, Houston, Texas 77258





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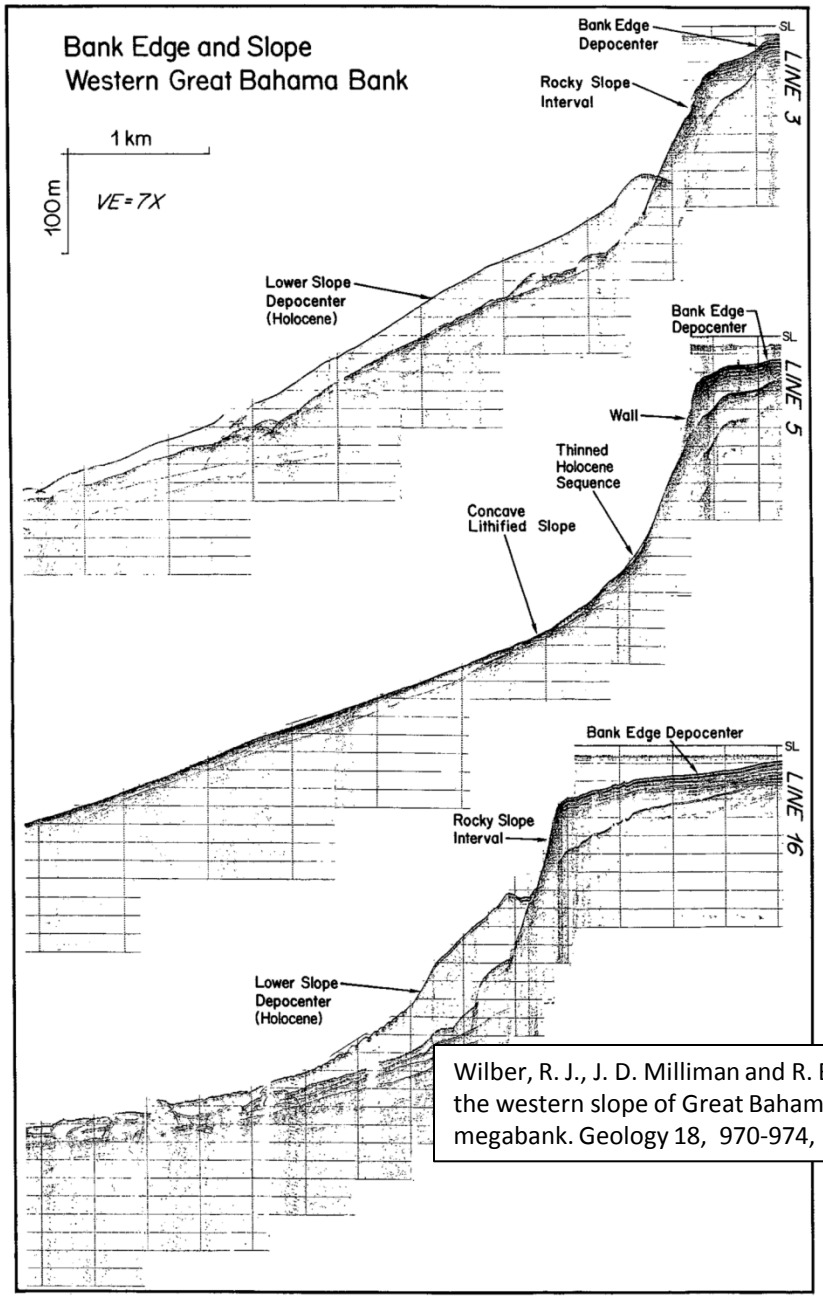


Figure 2. High-resolution seismic profiles of bank edge and slope of western Great Bahama Bank; see Figure 1 for location. Vertical scale is for seismic velocity of 1500 m/s in seawater. Each scale line is 25 ms two-way traveltime; uppermost scale line is sea level (SL). Horizontal scale is corrected to be dip parallel.

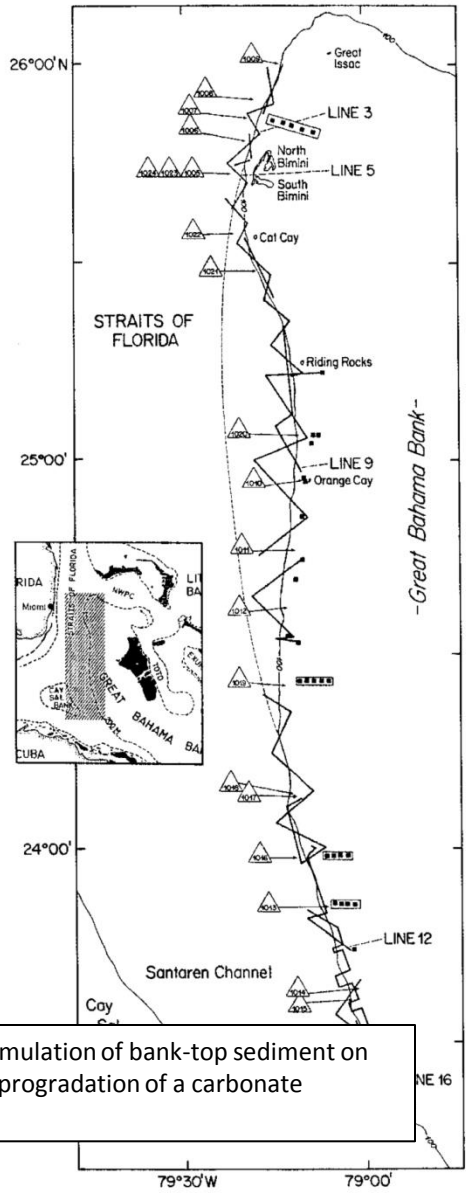
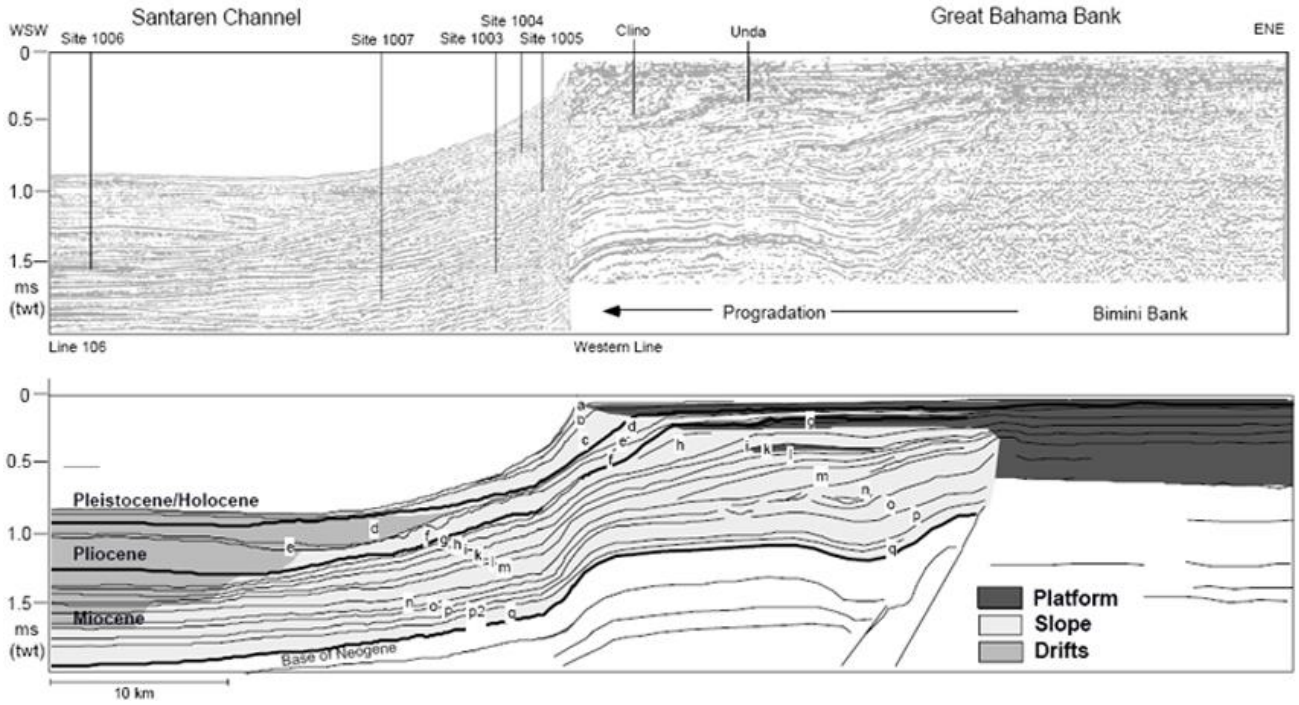


Figure 1. Reference map of study area along western Great Bahama Bank. Lines are high-resolution seismic profiles; profiles 3, 5, 12, and 16 are shown in Figures 2 and 3. Triangles are *Delta* dive sites. Dashed line spans embayed segment of bank margin discussed in text.

Wilber, R. J., J. D. Milliman and R. B. Halley: Accumulation of bank-top sediment on the western slope of Great Bahama Bank: Rapid progradation of a carbonate megabank. Geology 18, 970-974, 1990.

What is the Connection Between Whitings and the Growth of the Bahamas?



Dust and Fe

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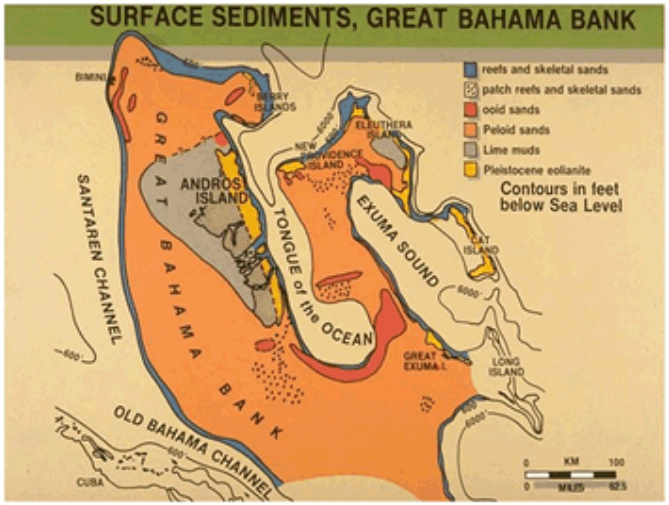
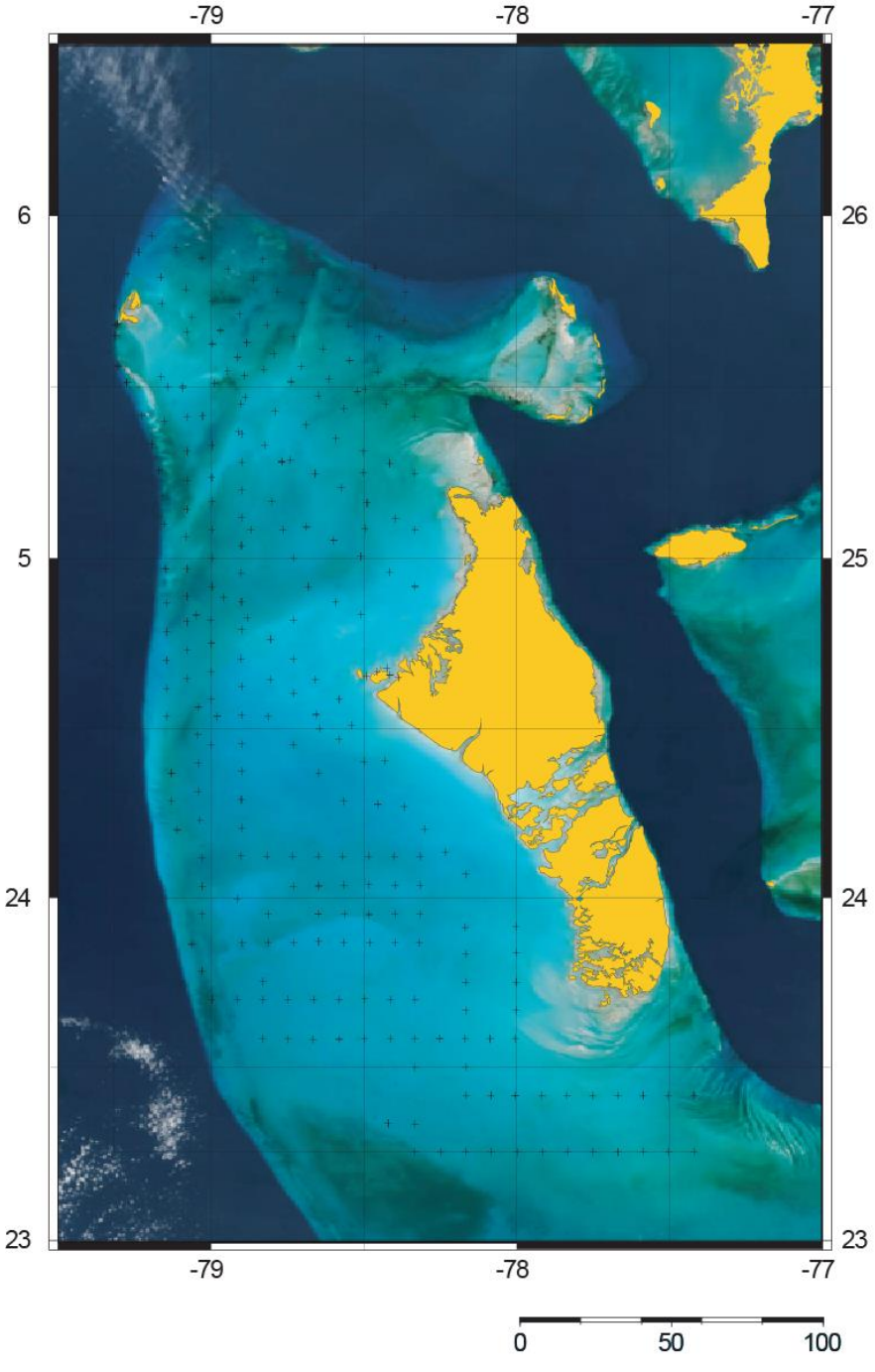
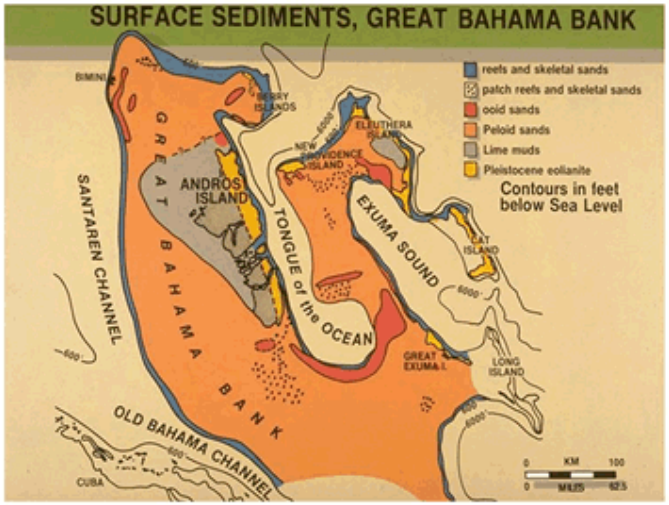
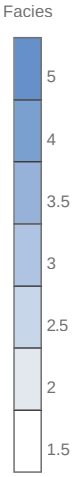
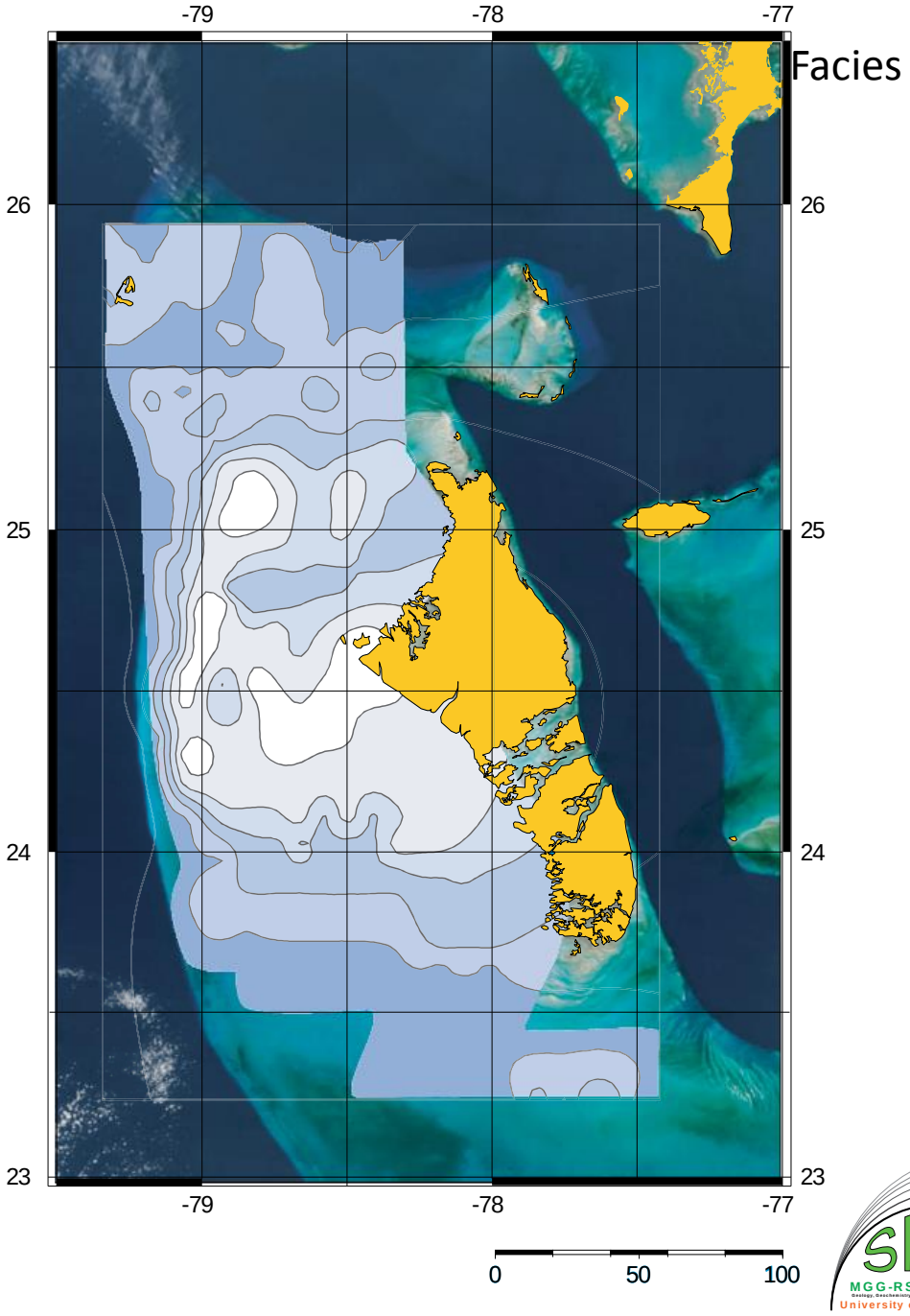




Reijmer, J. J. G., P. K. Swart, T. Bauch, R. Otto, S. Roth and S. Zechel: A reevaluation of Facies on Great Bahama Bank I: New Facies Maps of Western Great Bahama Bank Perspectives in Carbonate Geology: A Tribute to the Career of Robert Nathan Ginsburg, IAS Special Publication. P. K. Swart, G. P. Eberli and J. A. McKenzie. Oxford, Wiley-Blackwell. 41**: 29-46, 2009.**







Facies

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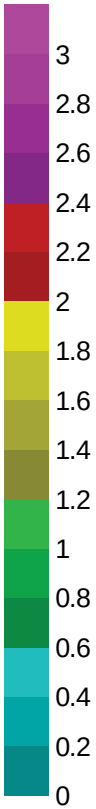
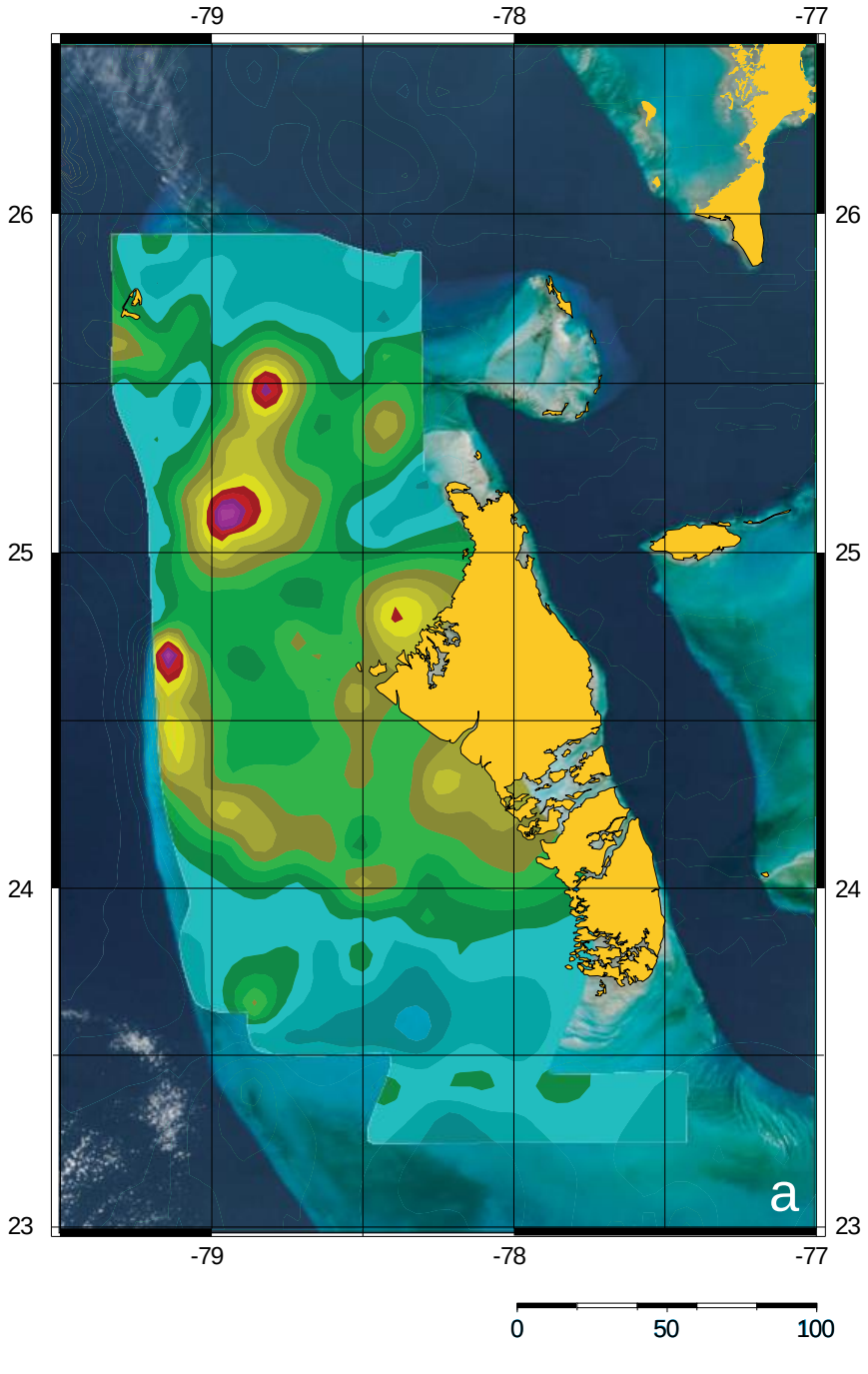
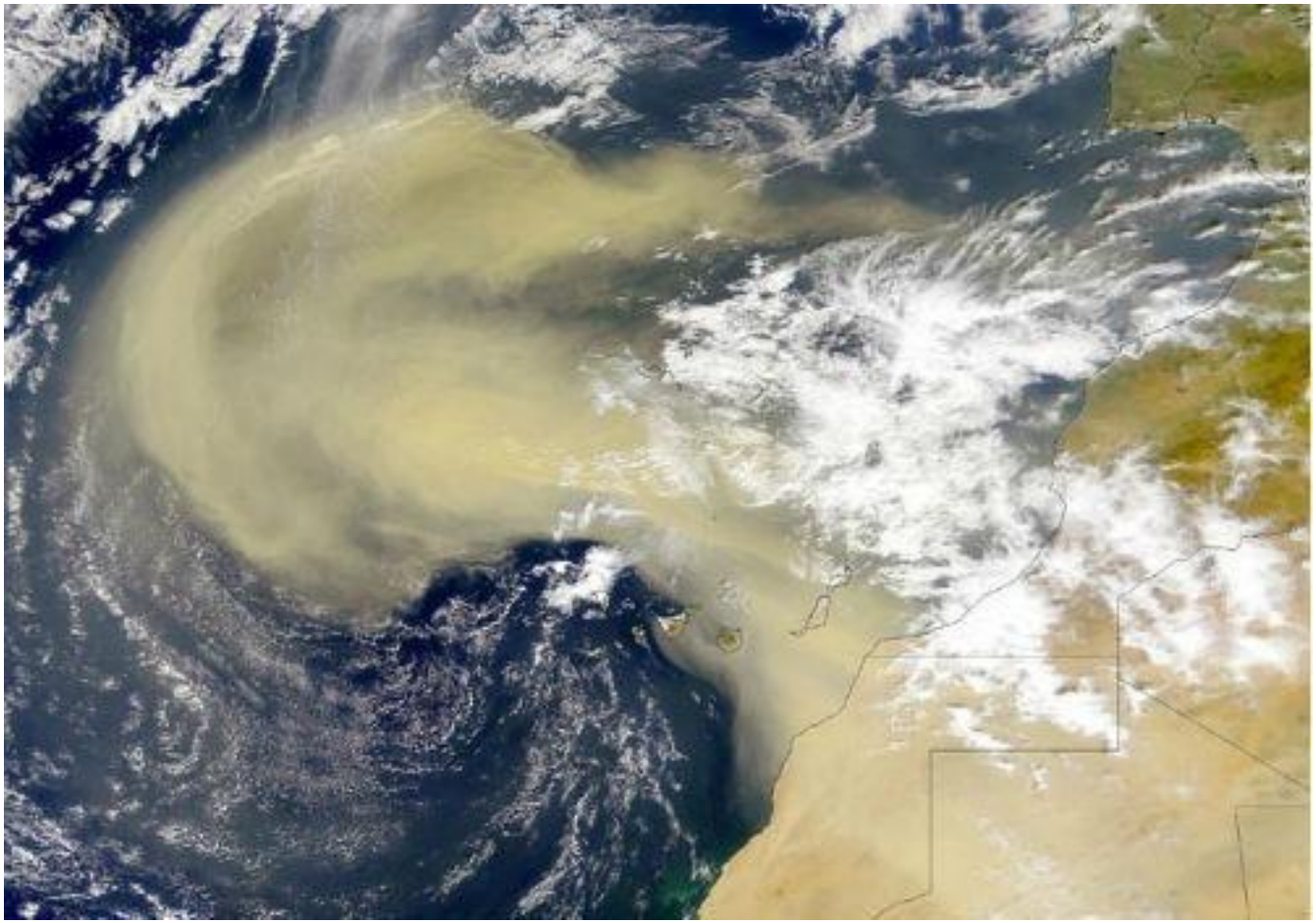
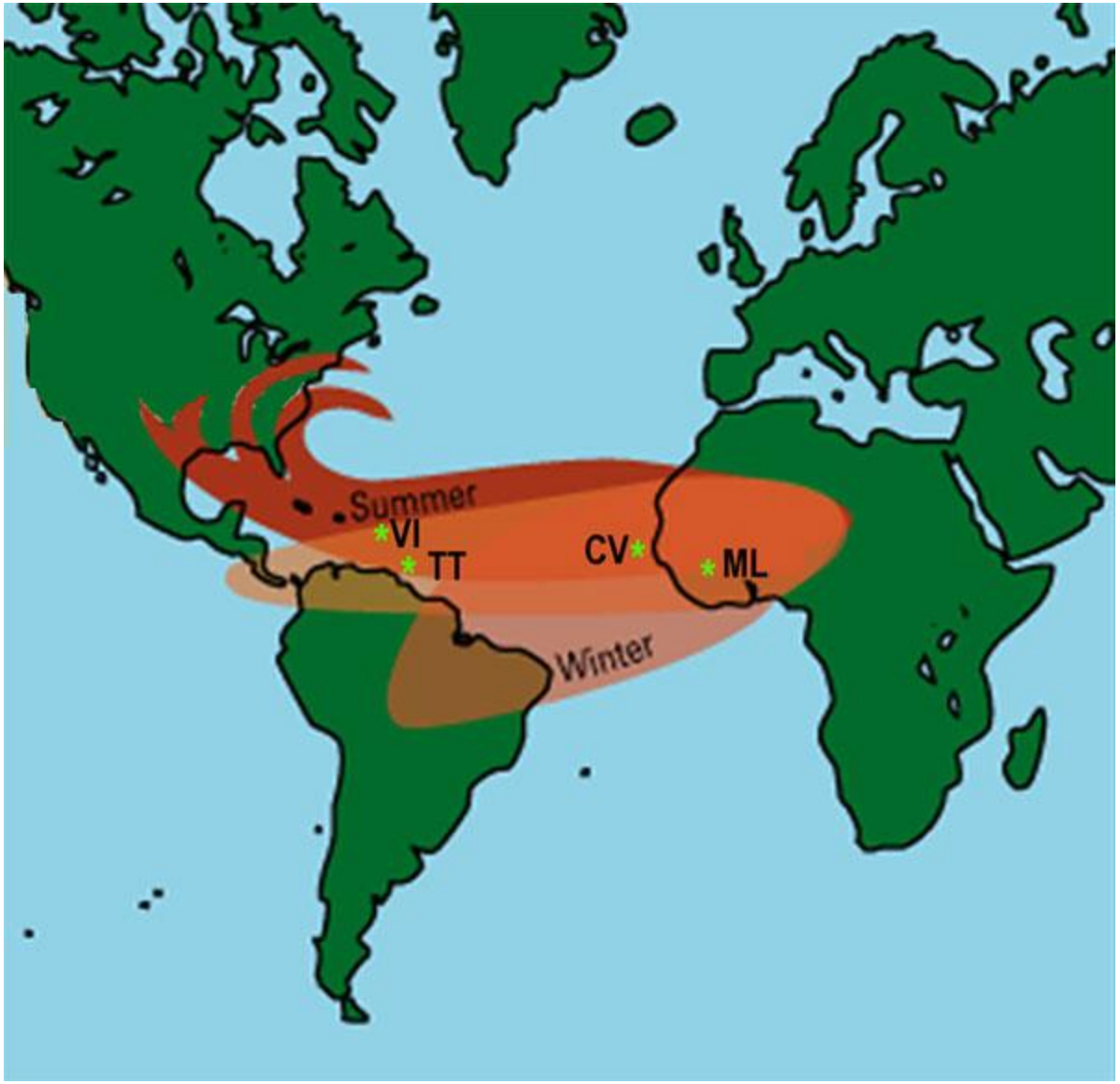
Insoluble %

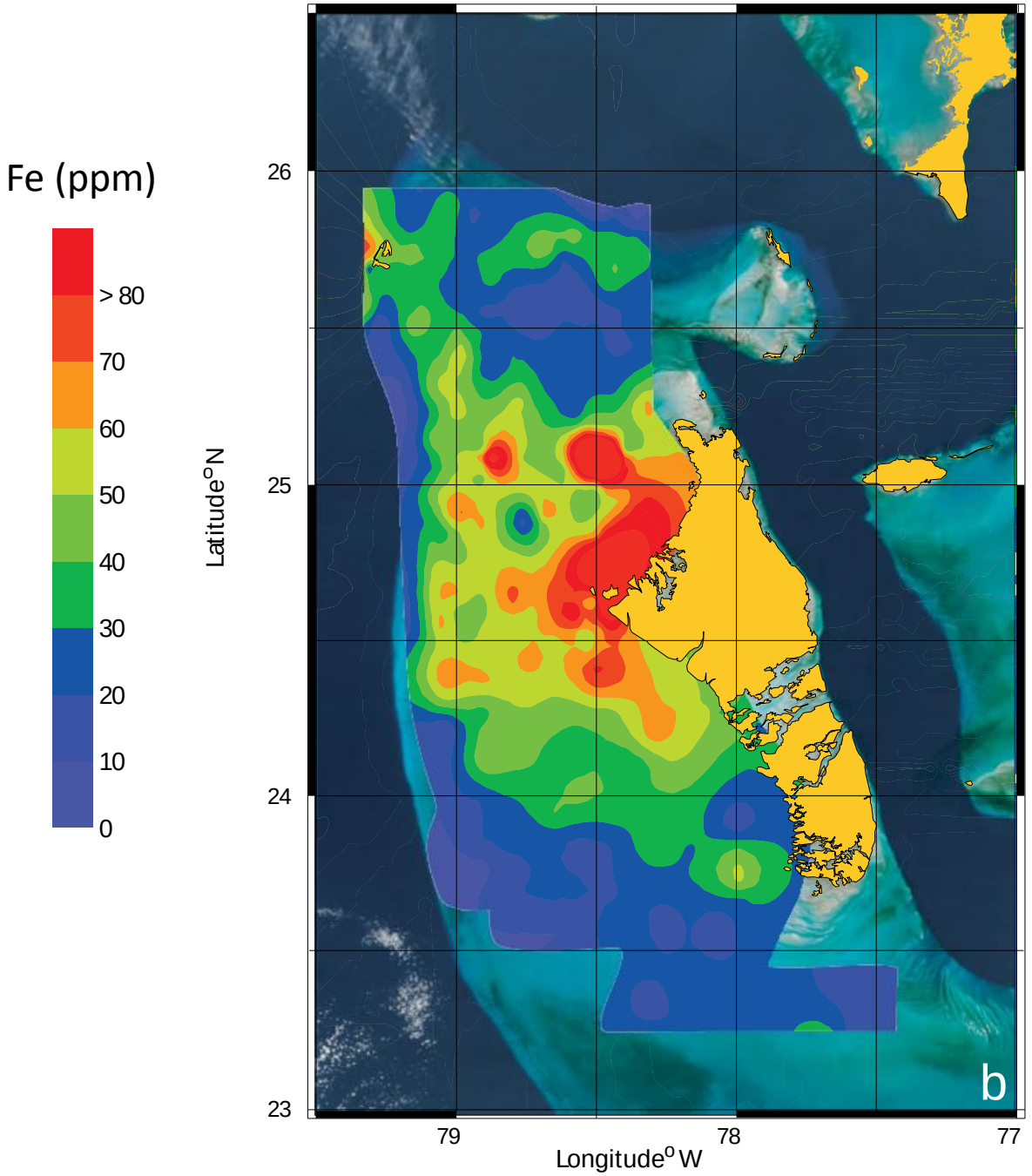








http://aerosols.hamptonu.edu/resources.html


Fe (ppm)
> 80
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60
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40
30
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Latitude°N
26
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79
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Longitude°W
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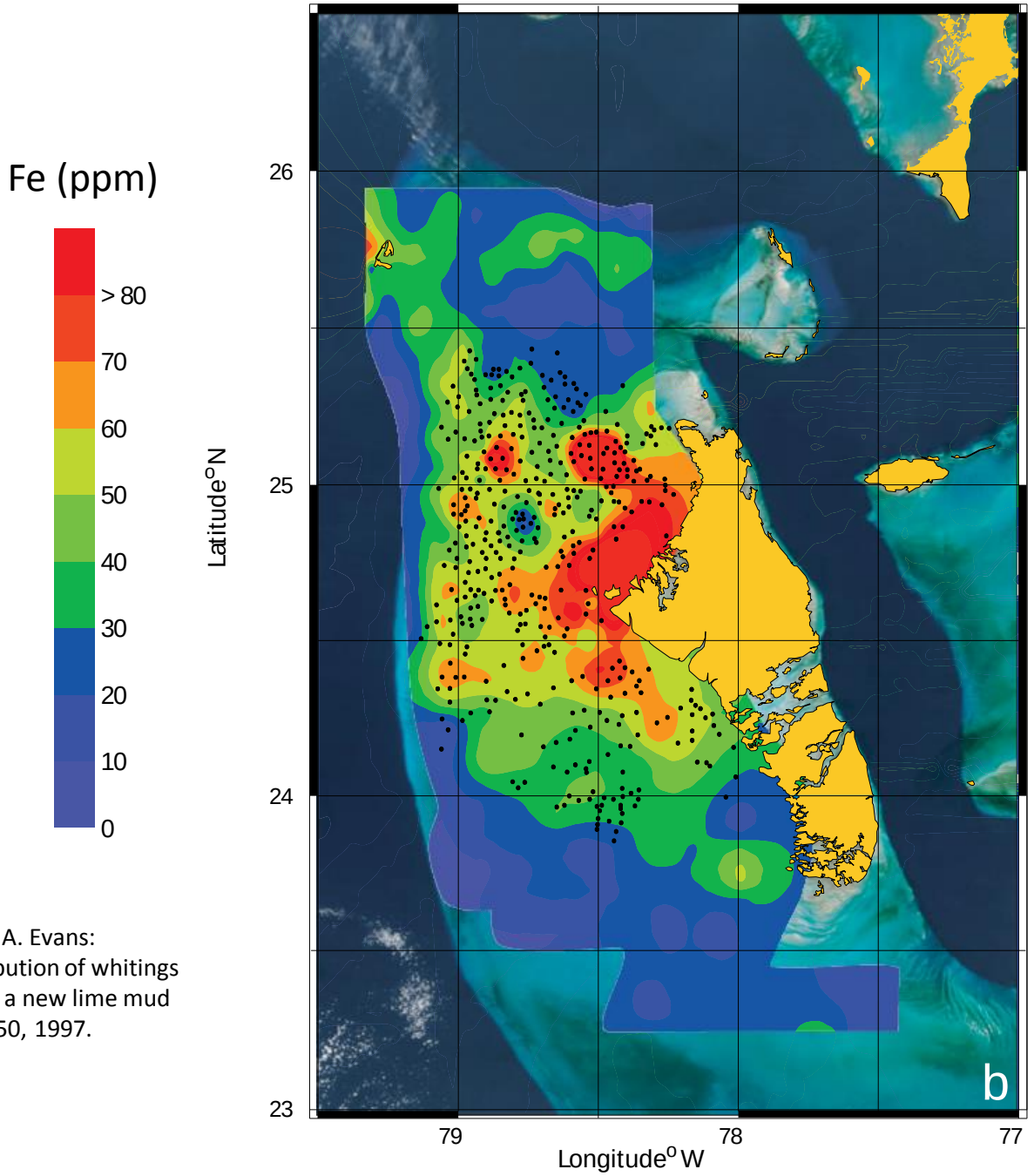
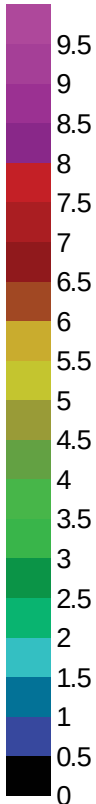
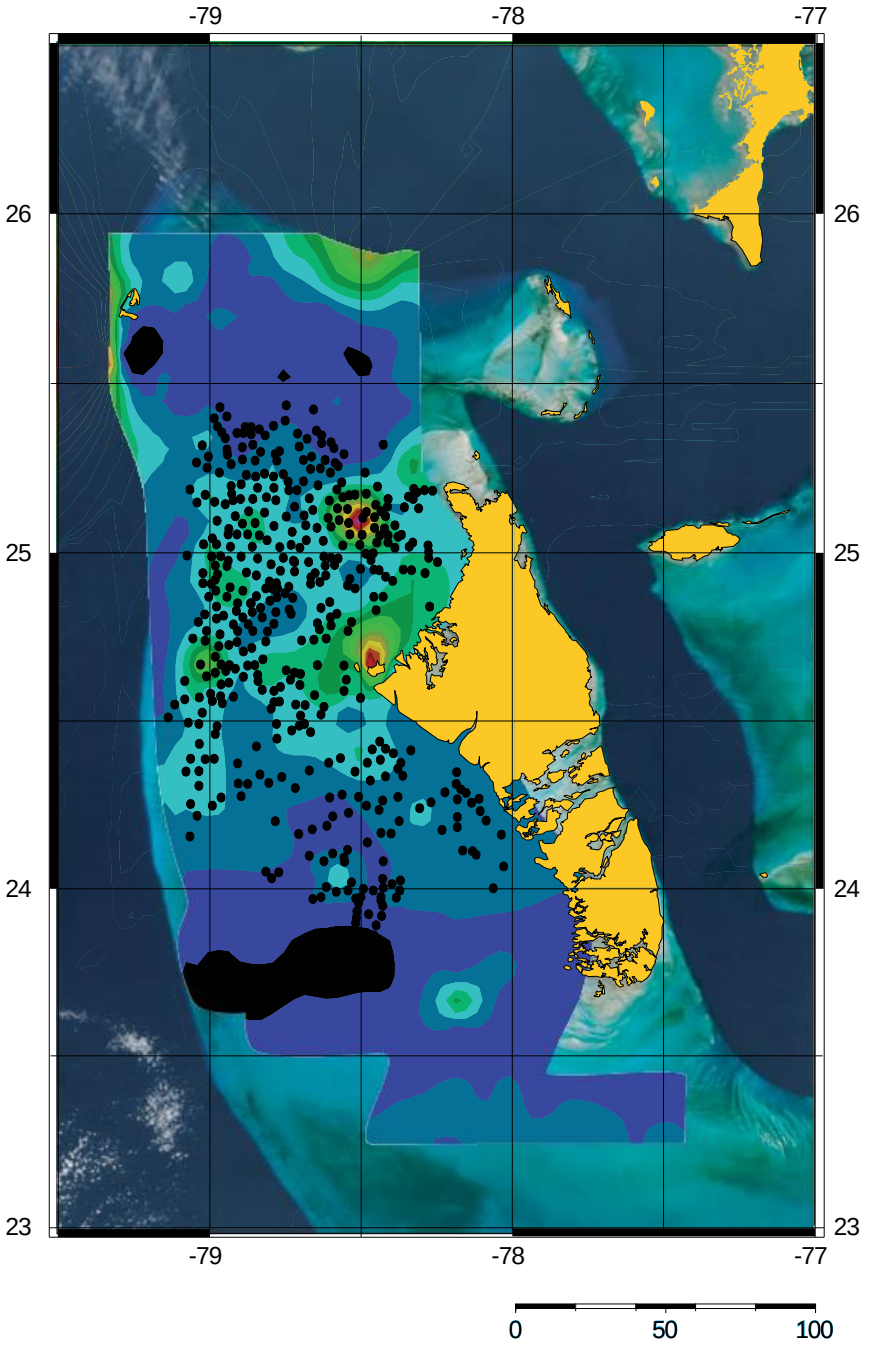


Whiting data from:
Robbins, L. L., Y. Tao and C. A. Evans: Temporal and spatial distribution of whitings on Great Bahama Bank and a new lime mud budget. Geology 25, 947-950, 1997.

Mn (ppm)





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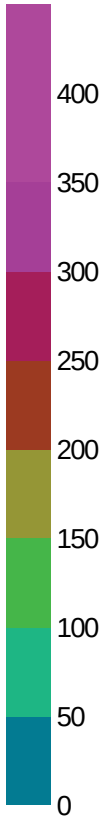
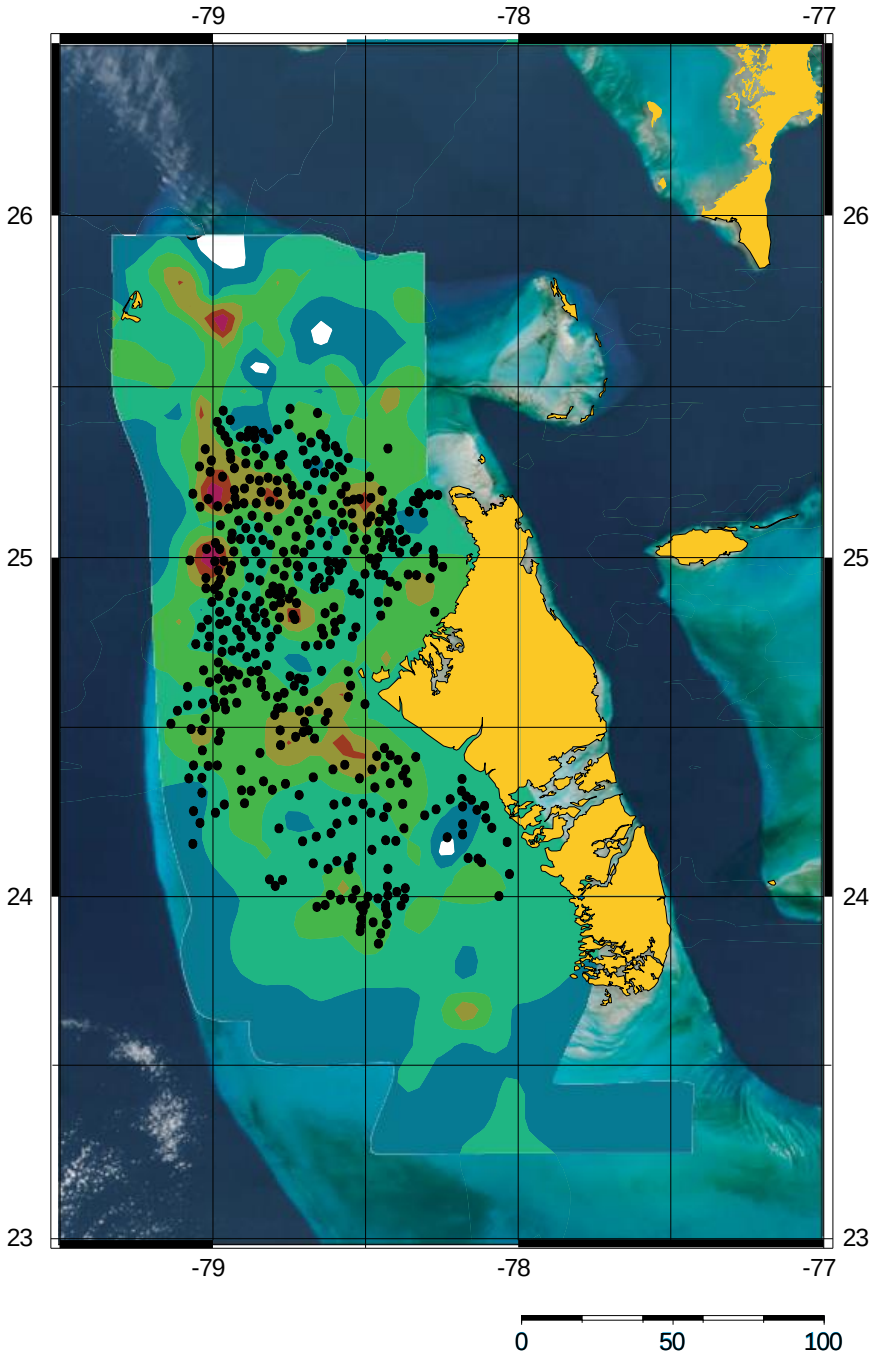
Al (ppm)





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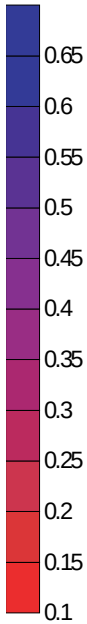
Ce (ppm)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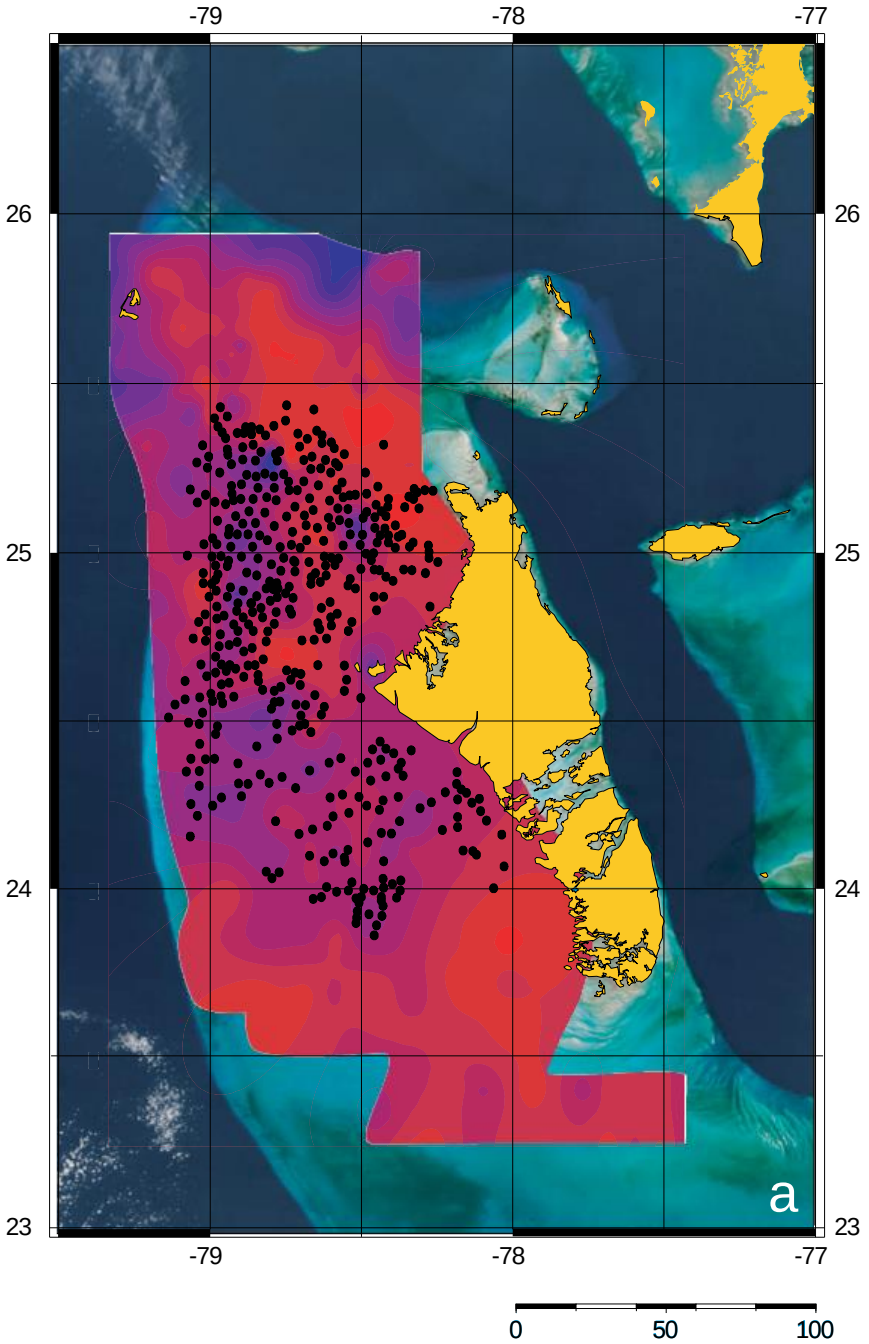
-79
-78
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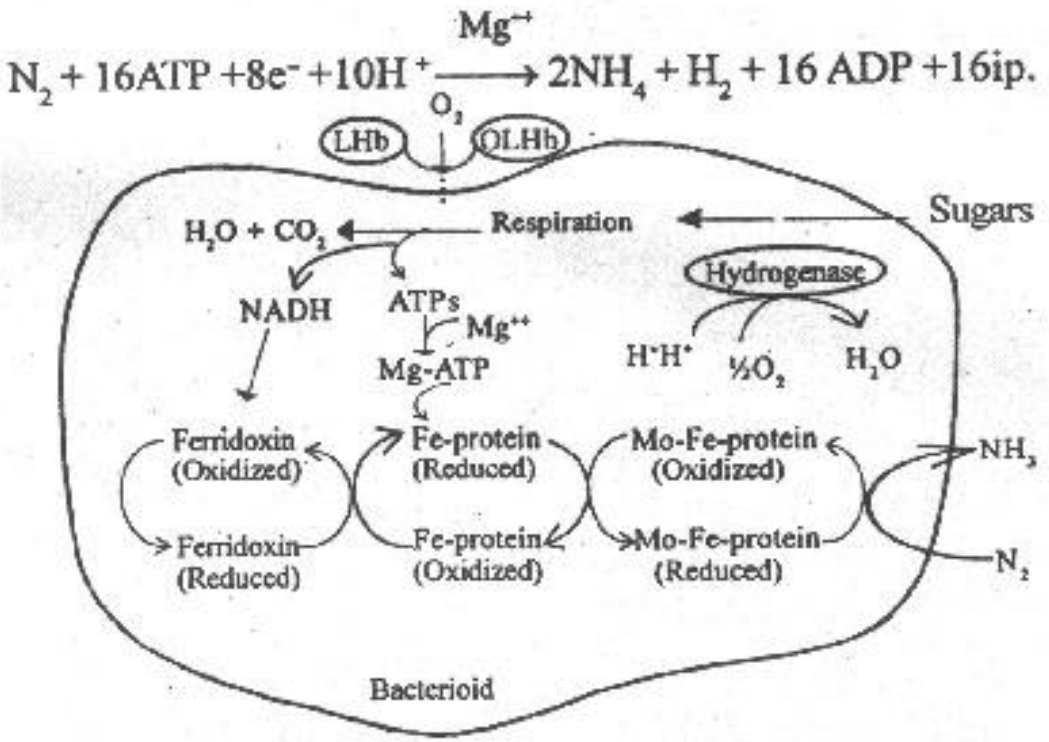
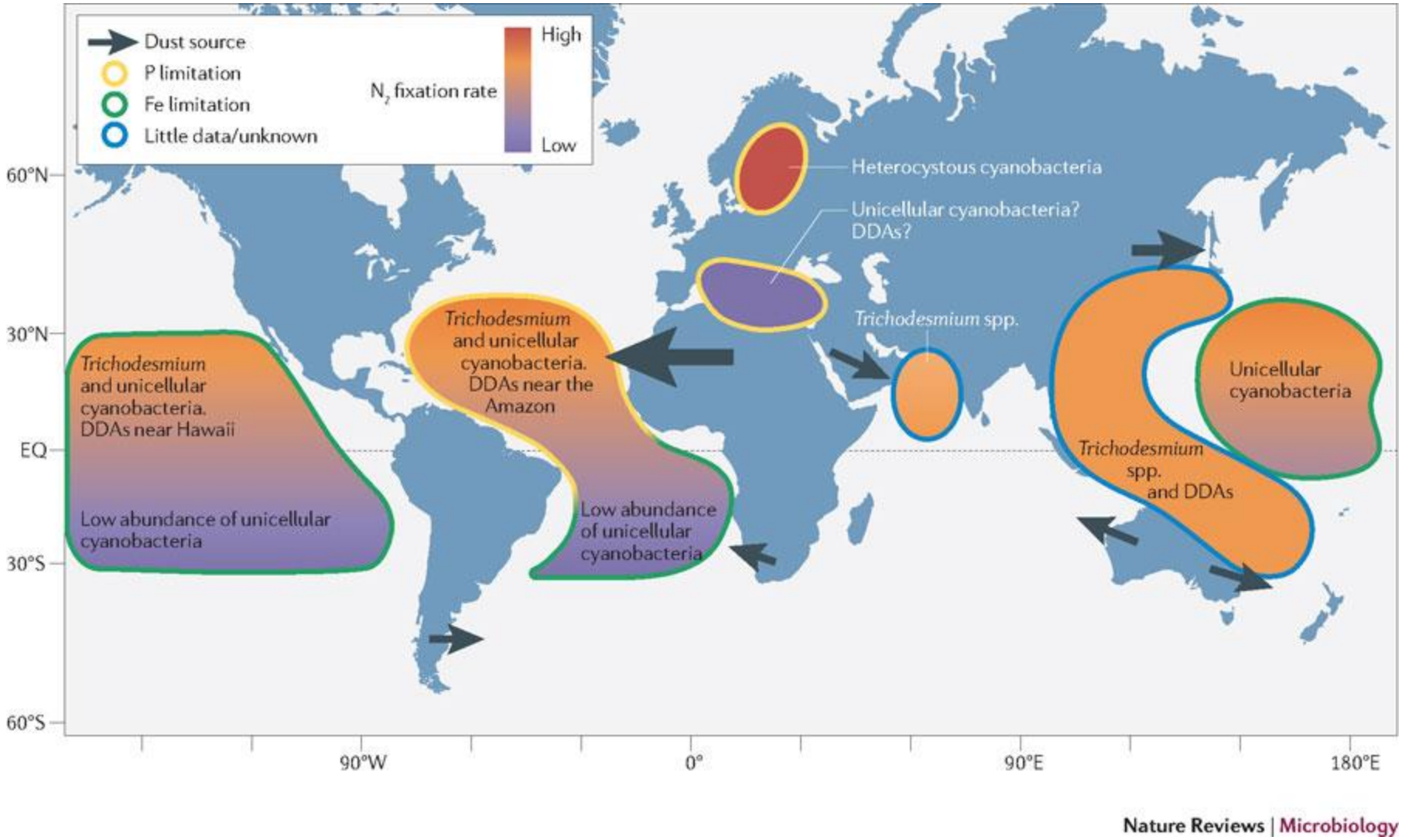
What is the connection between Cyanobacteria and Fe?

Cyanobacteria which are photosynthetic need about 10 times more Fe than algae to support the activity of N_2 fixation



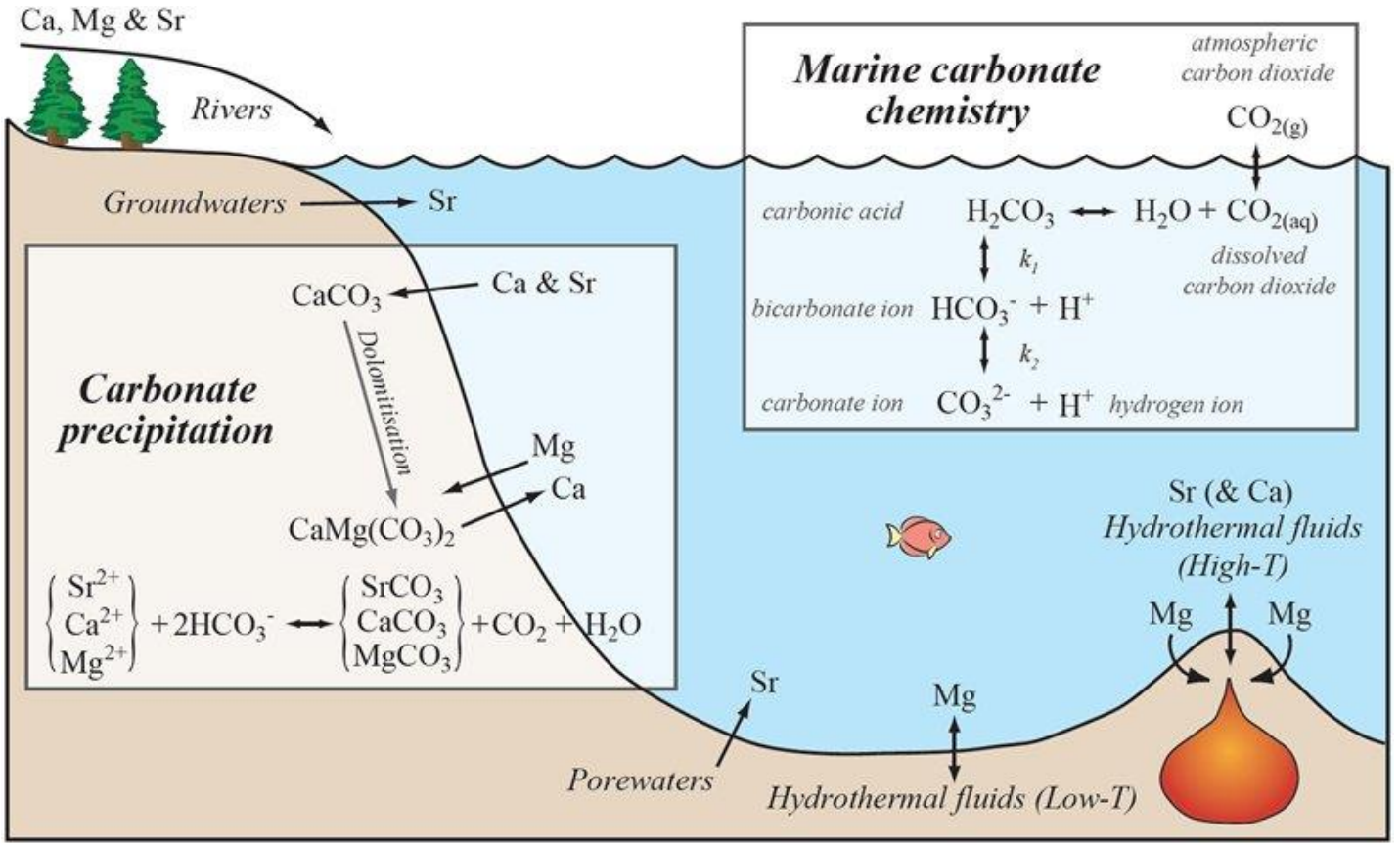
http://www.niir.org/books/book/plant-biotechnology-handbook/isbn-8186623833/zb,,75,a,3f,0,a/index.html



http://dornsife.usc.edu/labs/capone/summary/

What is the connection between Cyanobacteria and Whitings?

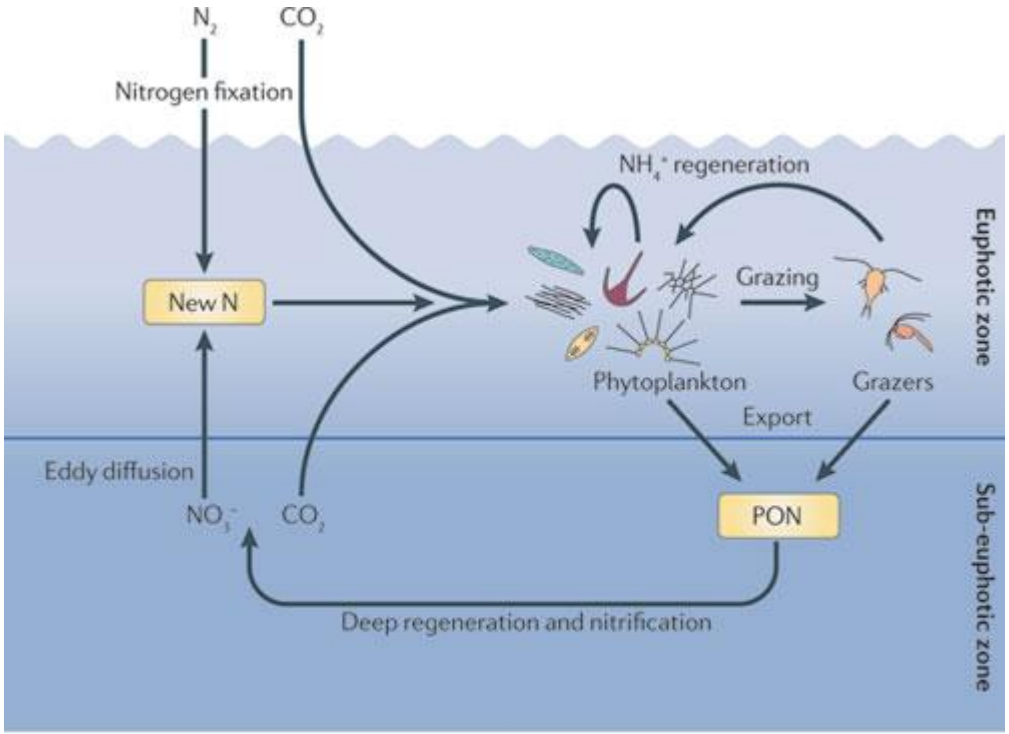
Photosynthesis by the Cyanobacteria cause a draw down in CO_2 and causes an increase in the saturation state of Calcium Carbonate.



http://www.southampton.ac.uk/oes/research/projects/understanding_changes_in_cenozoic_carbonate_chemistry.page

What is the benefit of the Cyanobacteria to the Community?

The fixation of N_2 provides N_2 to all organisms in the Environment promoting growth of seagrasses and algae.



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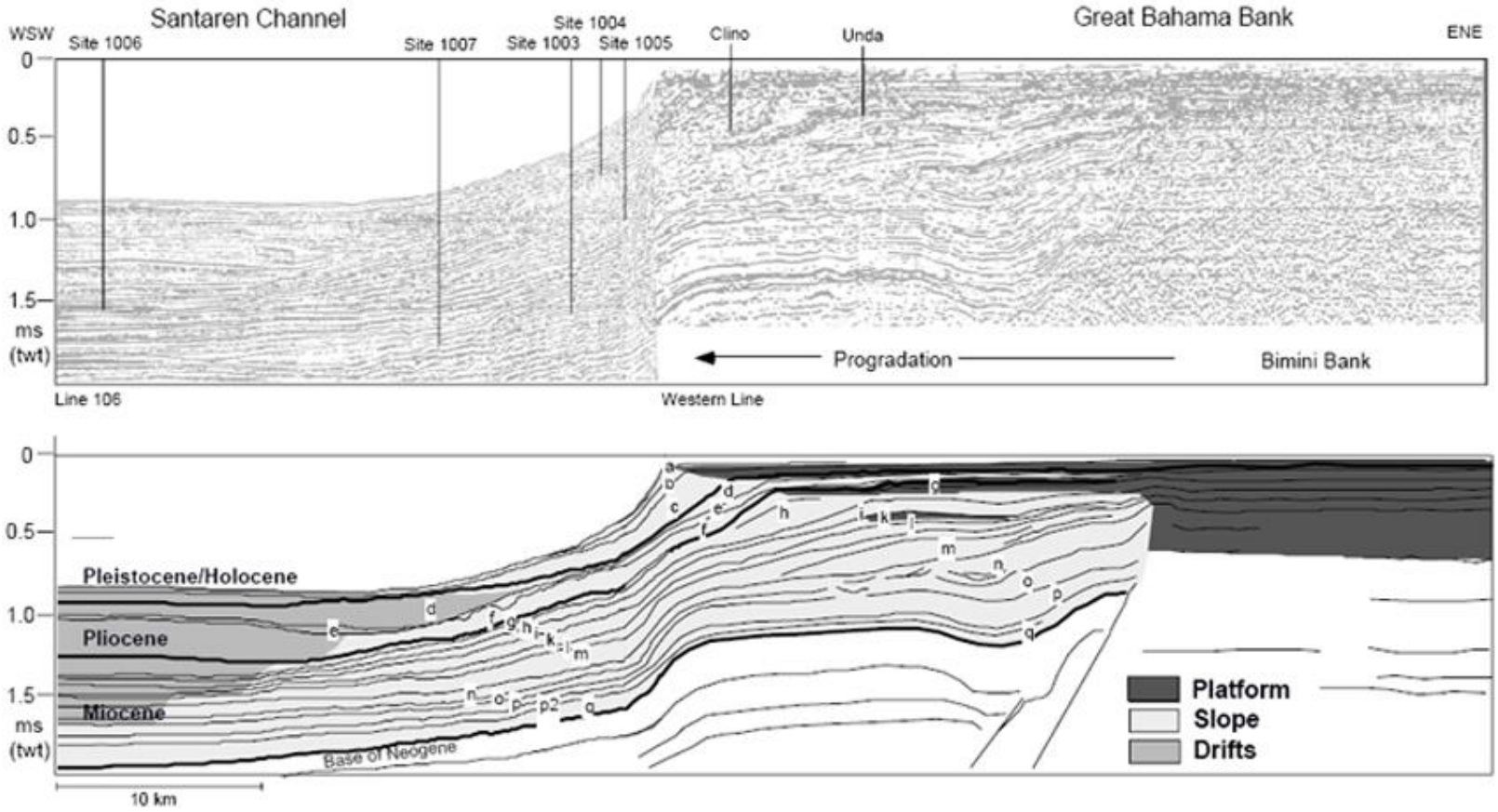
http://dornsife.usc.edu/labs/capone/summary/

What are the Consequences?

During periods of high Fe delivery the production of carbonate increases and the platform progrades more rapidly.

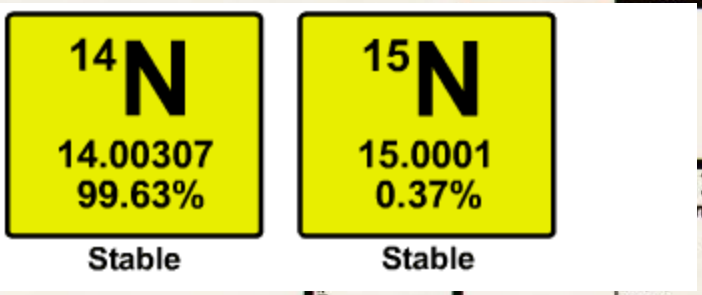


Eberli, G. P.: The record of Neogene sea-level changes in the prograding carbonates along the Bahamas transect-Leg 166 synthesis. Proc. ODP Sci. Res. P. K. Swart, G. P. Eberli, M. J. Malone and J. F. Sarg. 166**: 167-177, 2000.**

Strong Supporting Evidence

"Smoking Gun"

- All elements ha
one isotope.
- Some of these
some unstable
- Nitrogen has two stable isotopes (^{14}N and ^{15}N)
- Changes in the abund
the less abundant isot
relative to ^{14}N reflect b
and physical processe
can be used as tracers of such processes
- All organisms contain N and therefore some ^{15}N



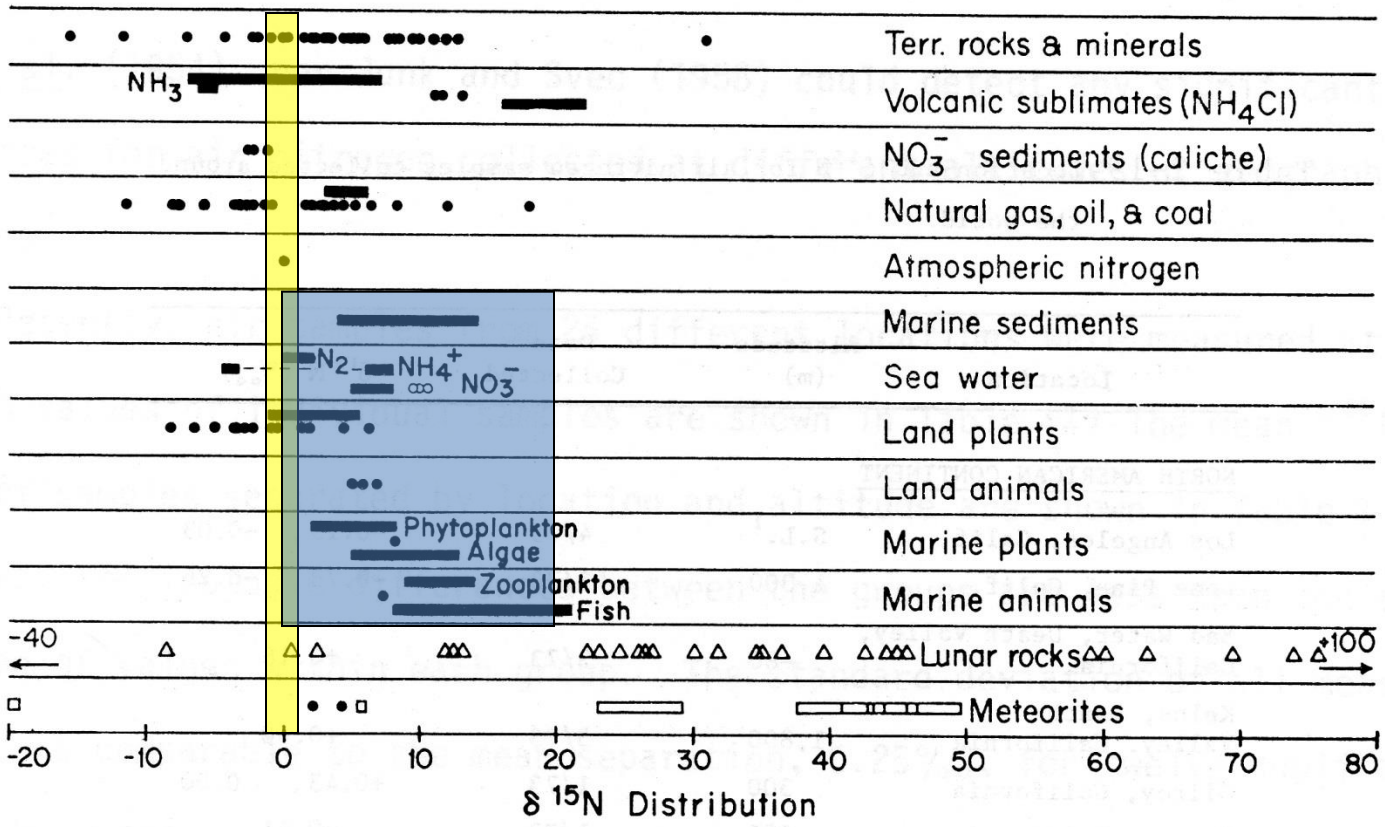
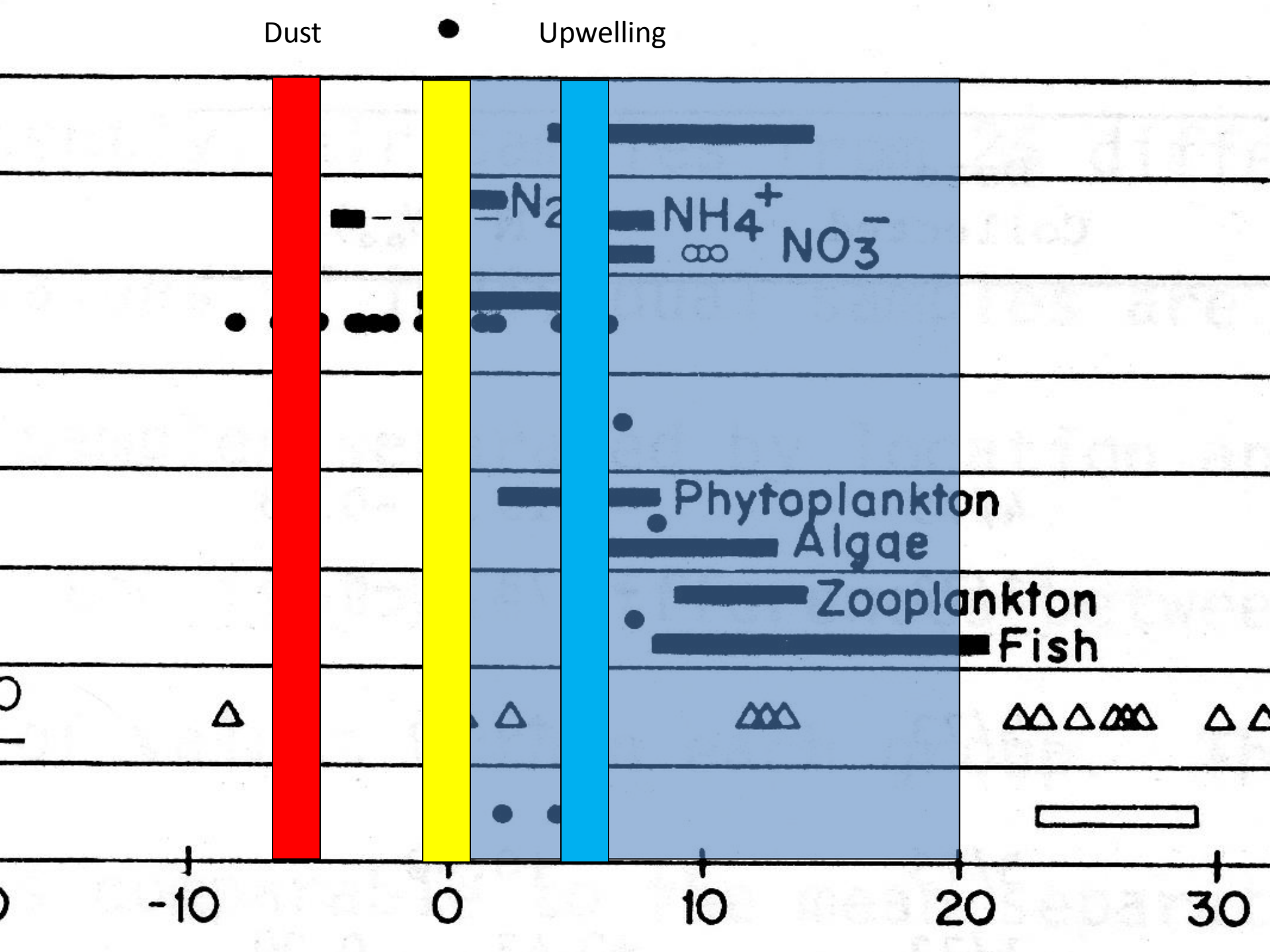
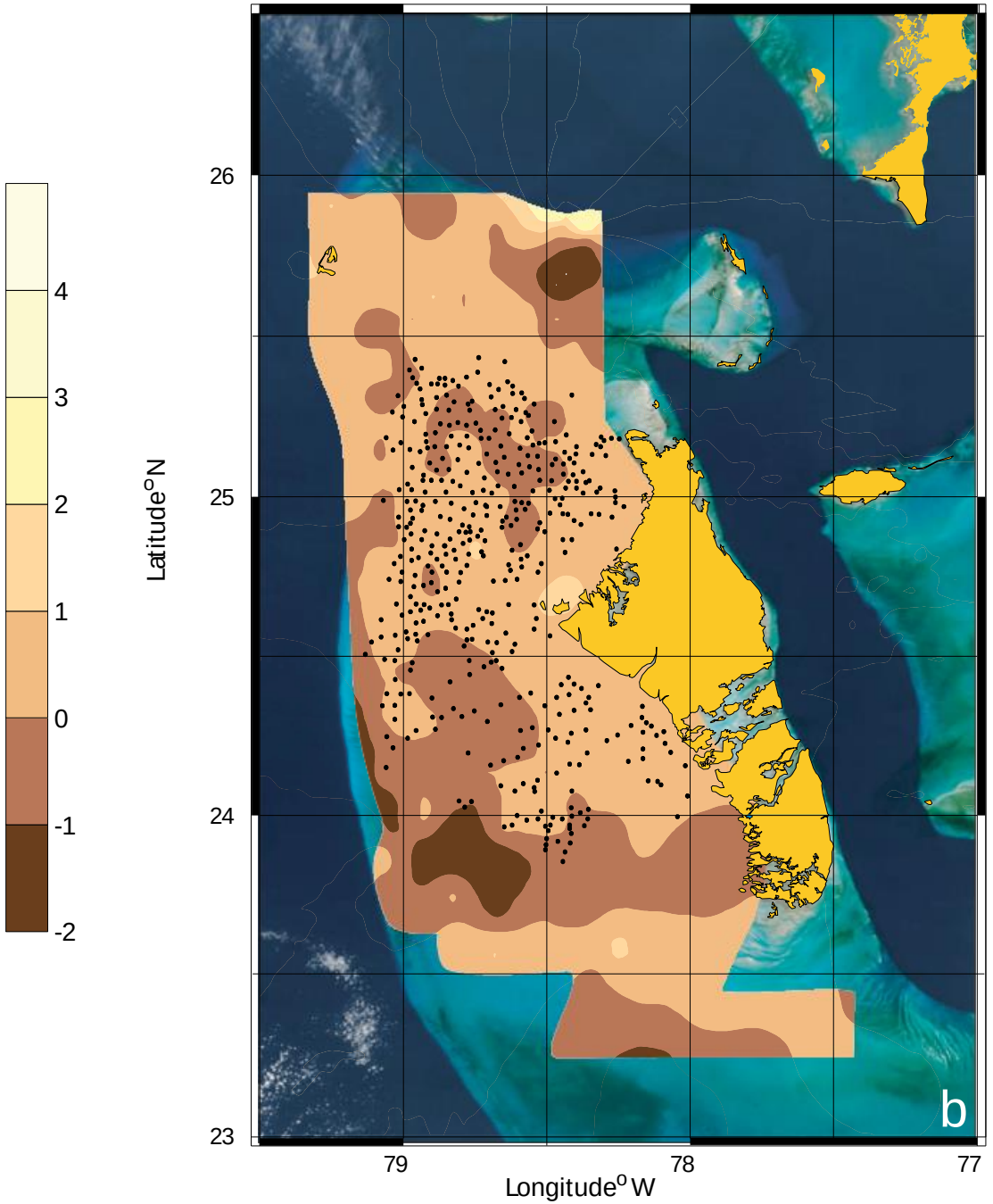
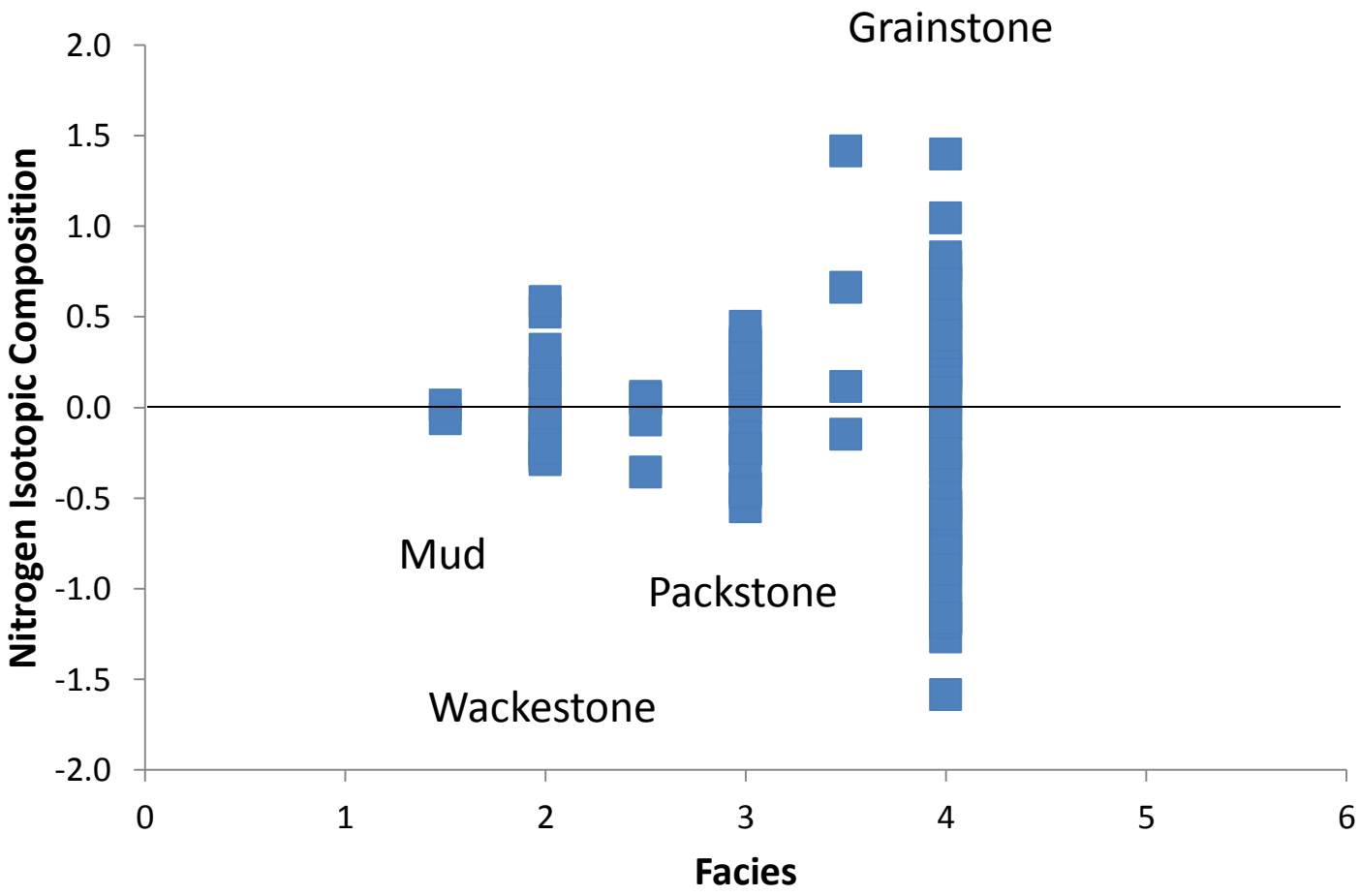


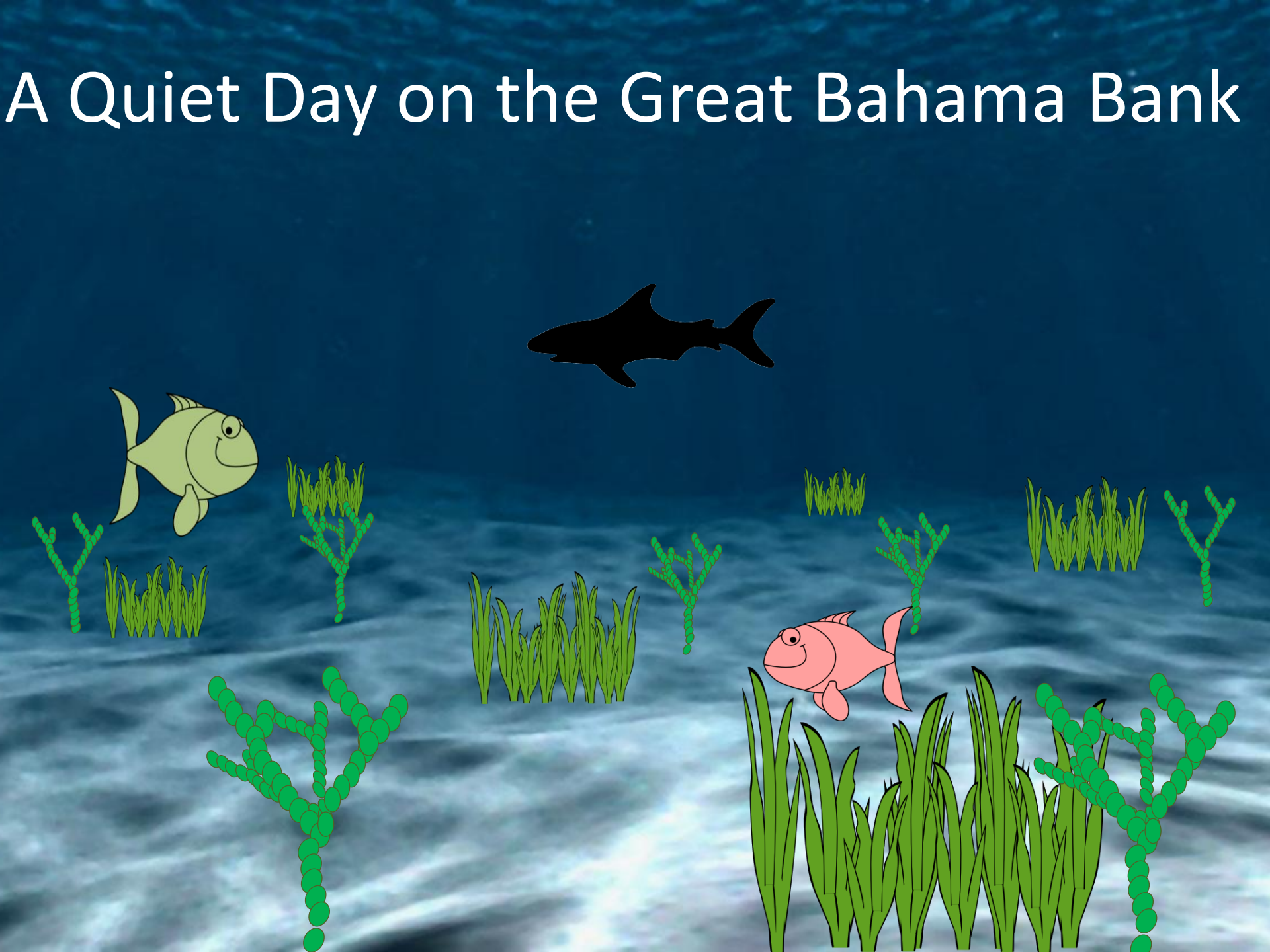
Figure 2-15. General distribution of $\delta^{15}N$ for various natural substances (revised after Miyake and Wada, 1967; Wlotzka, 1972; and Kaplan, 1975)

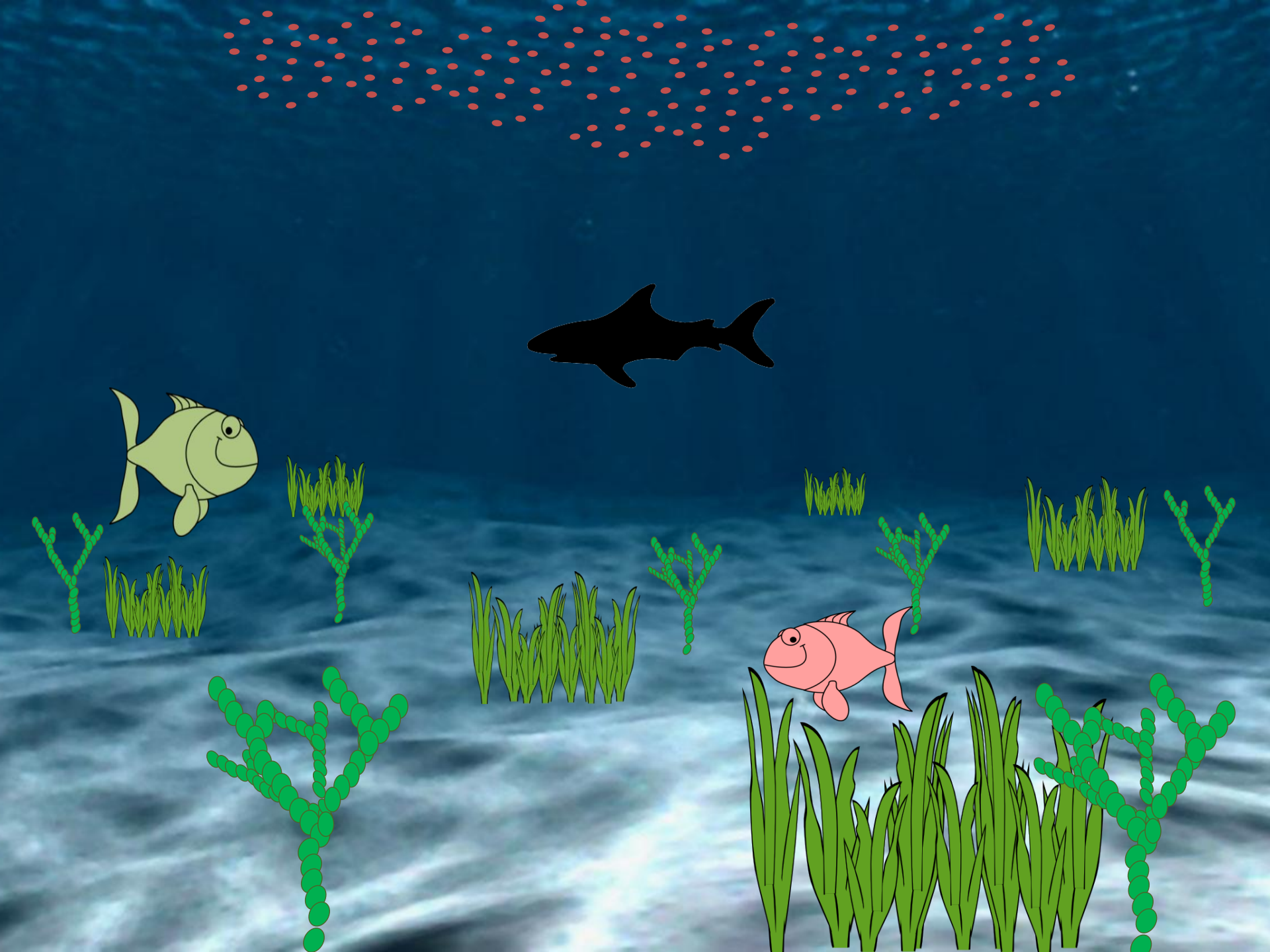

Dust
Upwelling
N_2
NH_4^+
NO_3^-
Phytoplankton
Algae
Zooplankton
Fish
-10
0
10
20
30

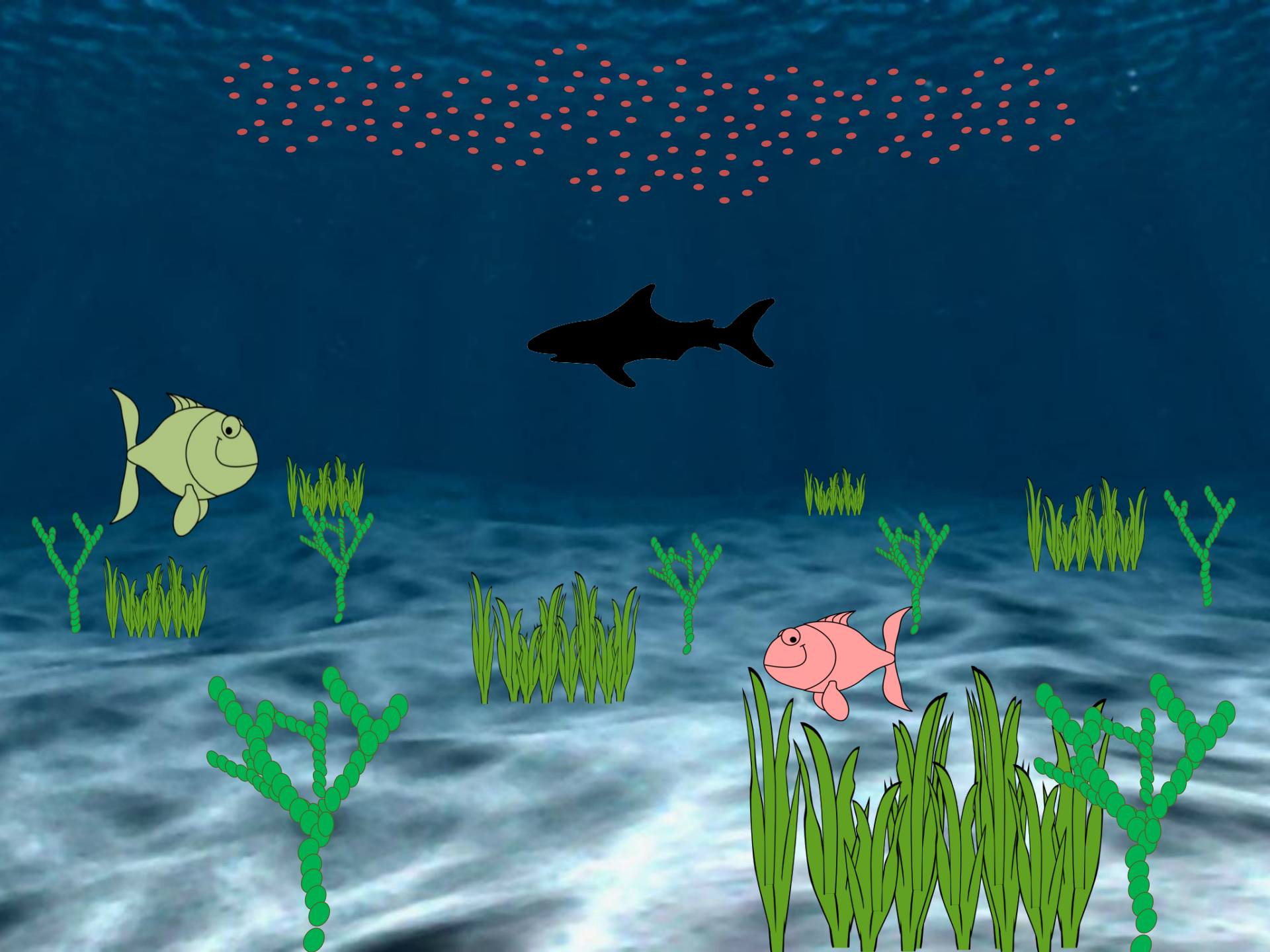

4
3
2
1
0
-1
-2
26
25
24
23
Latitude°N
79
78
77
Longitude° W
b

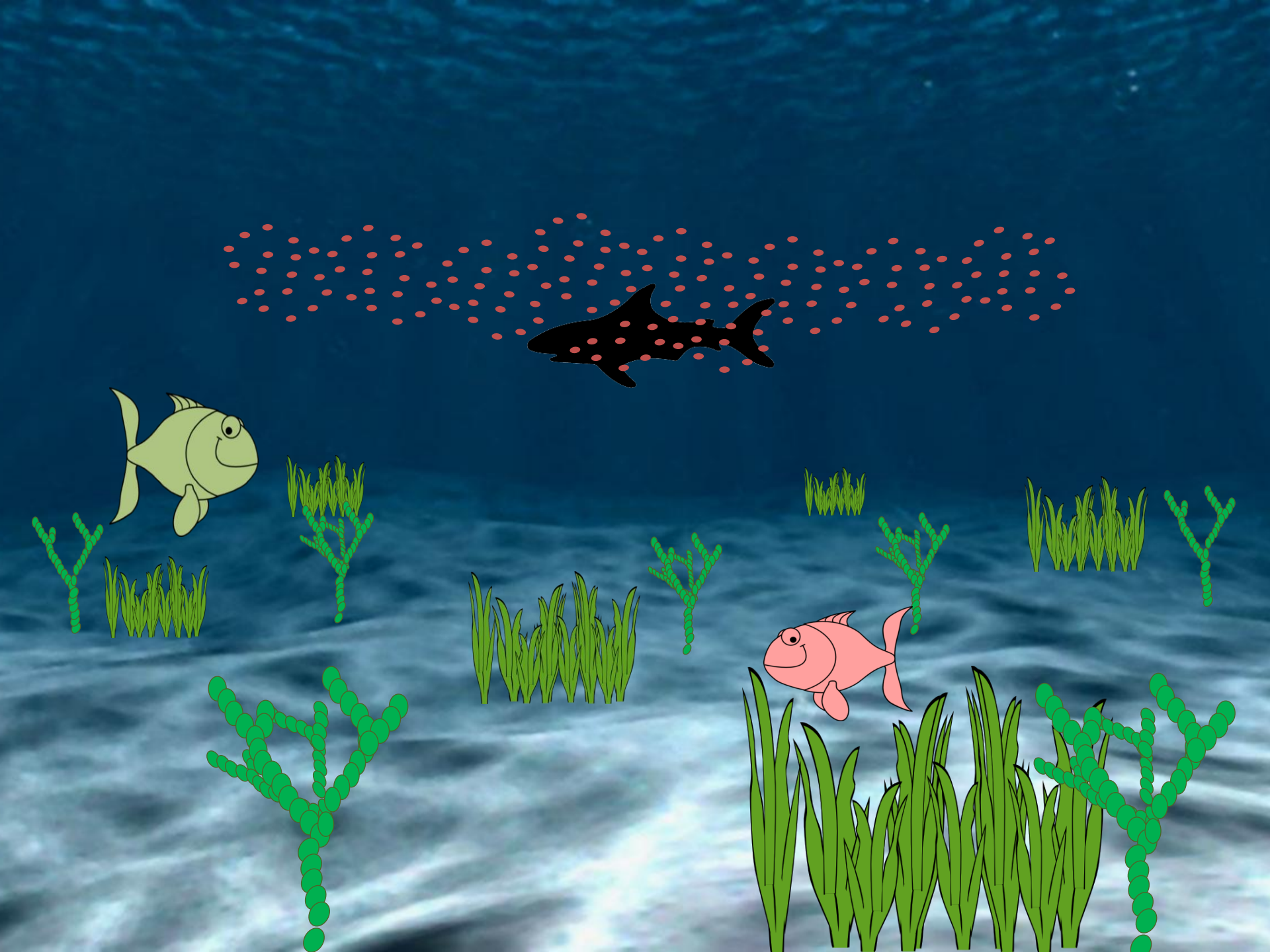


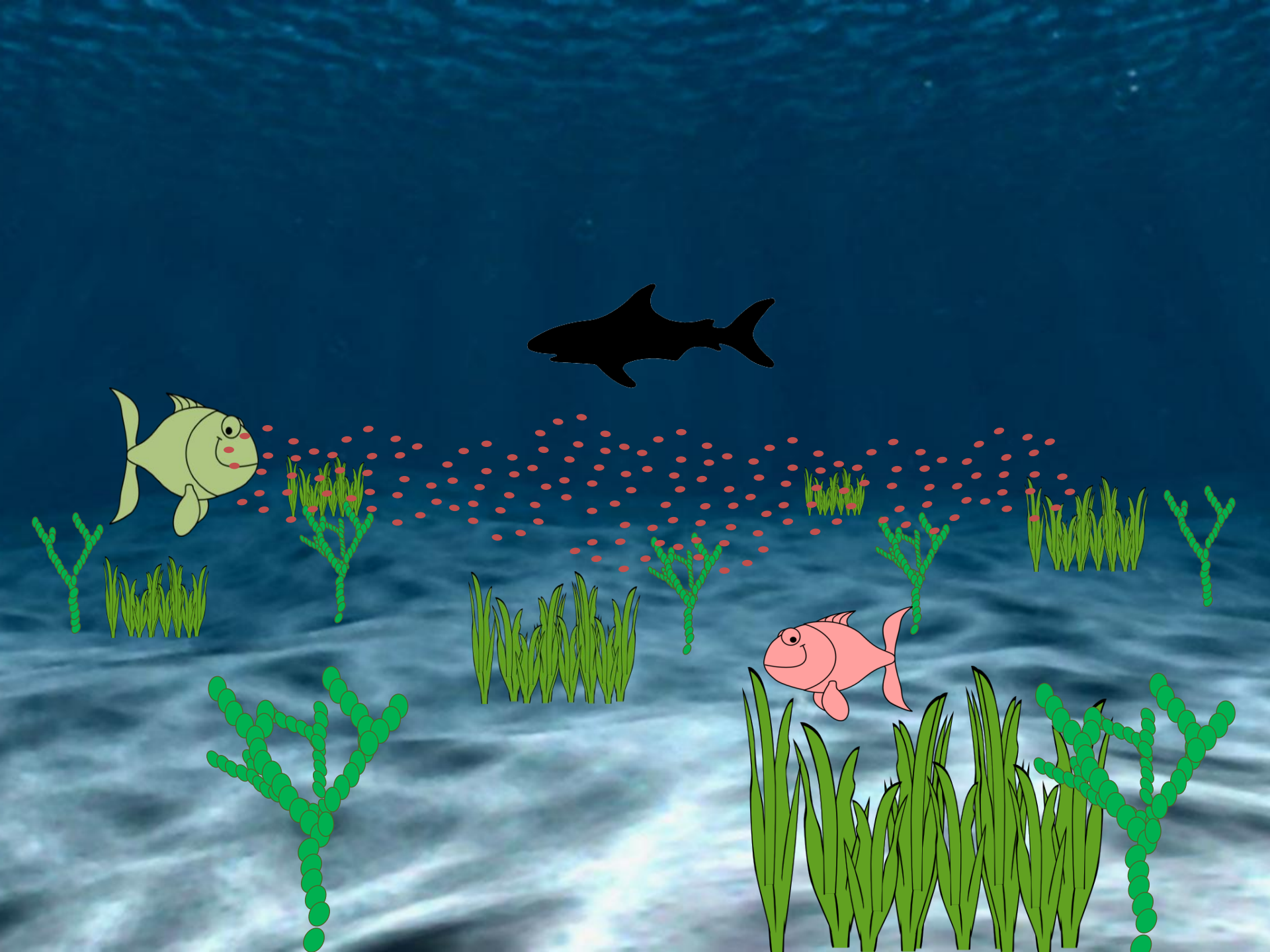
A Quiet Day on the Great Bahama Bank

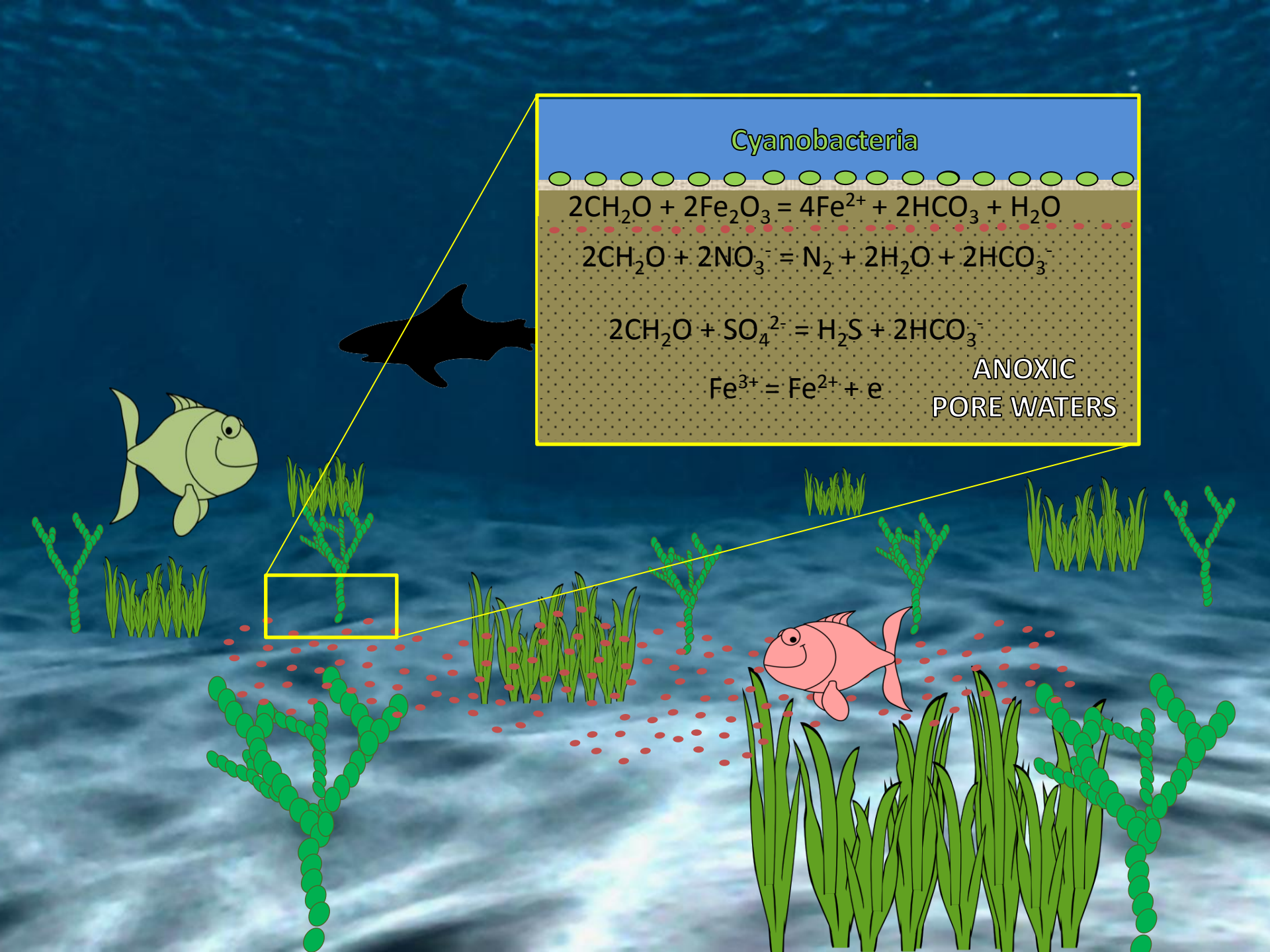


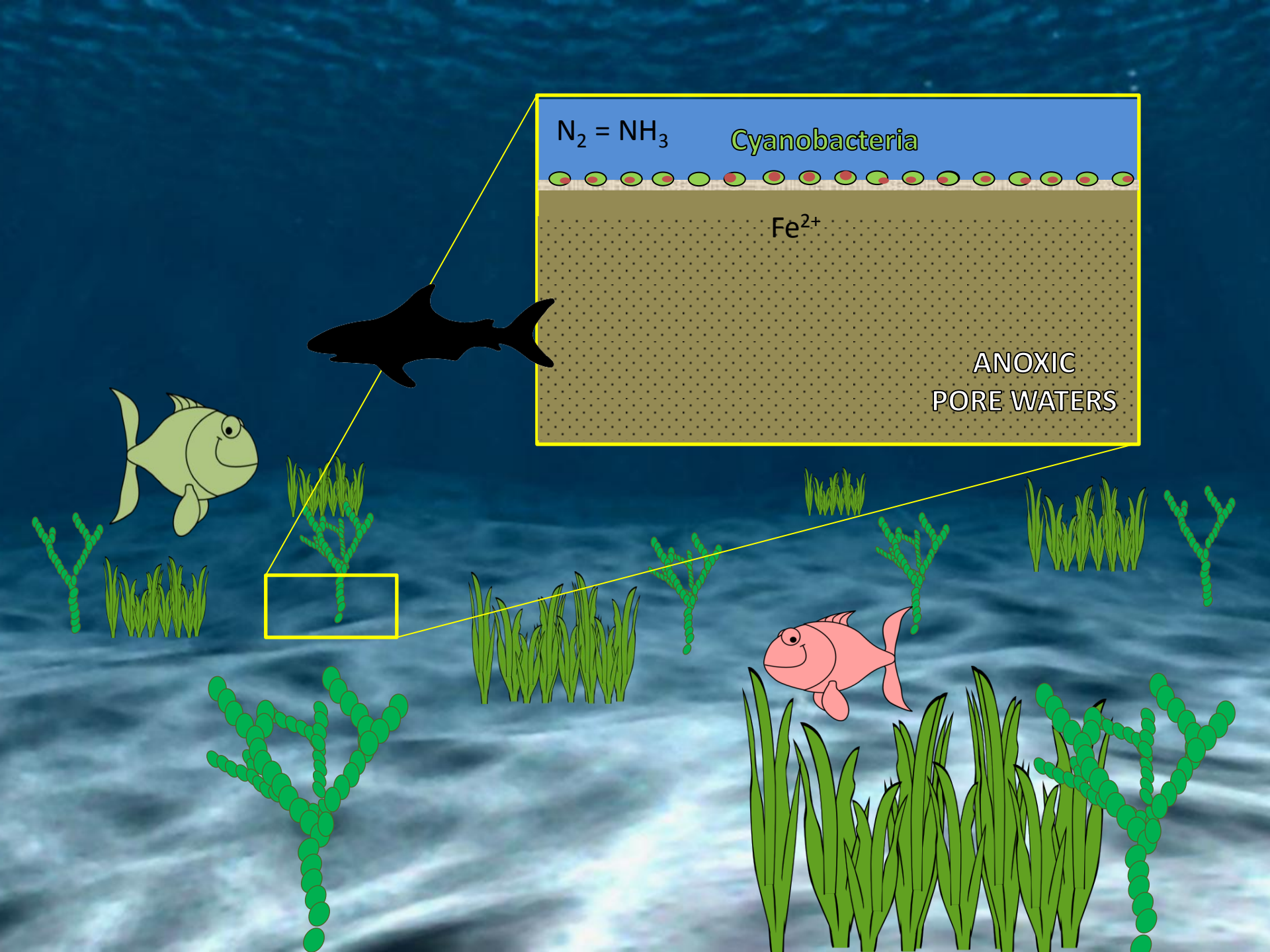


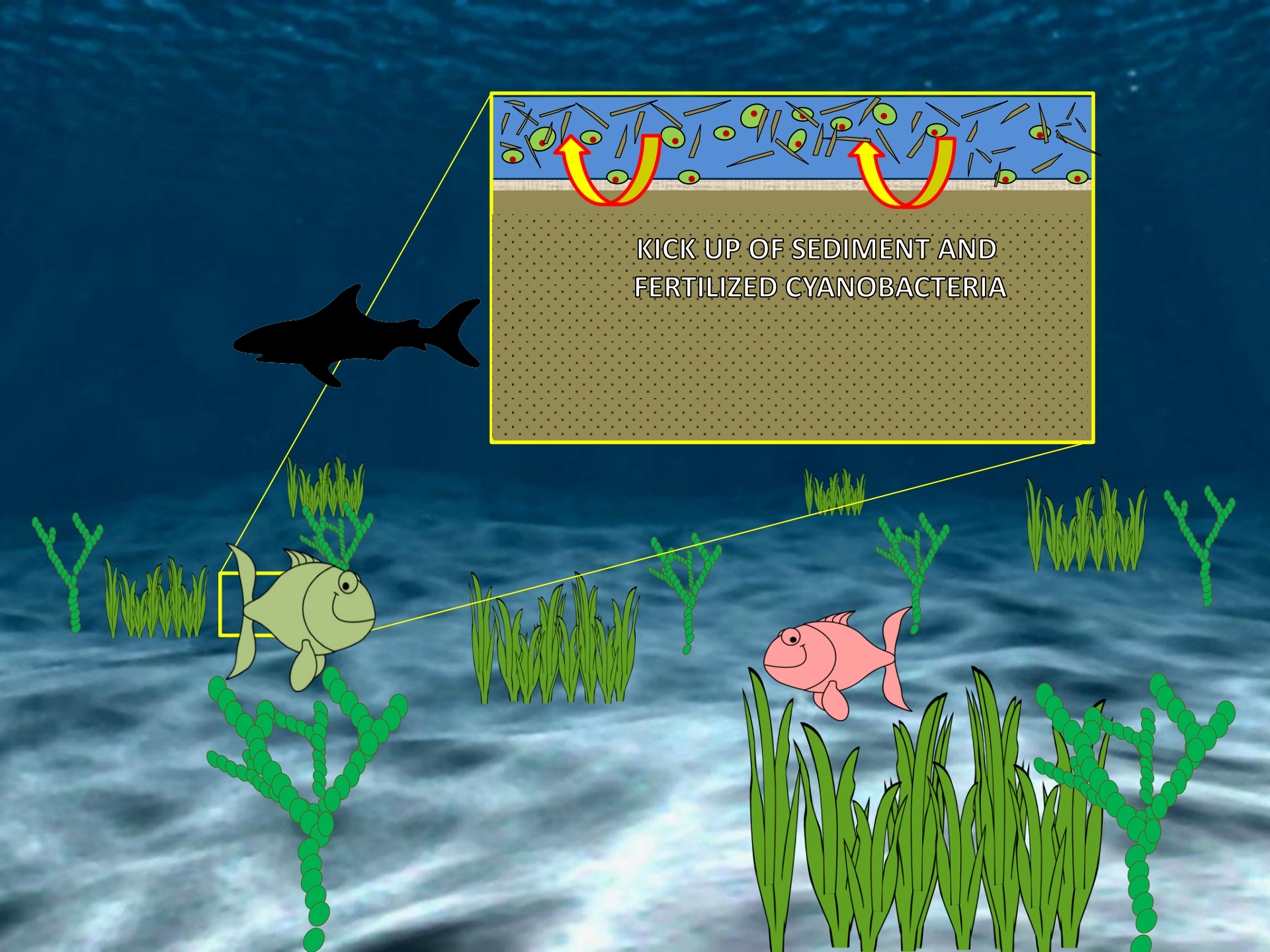


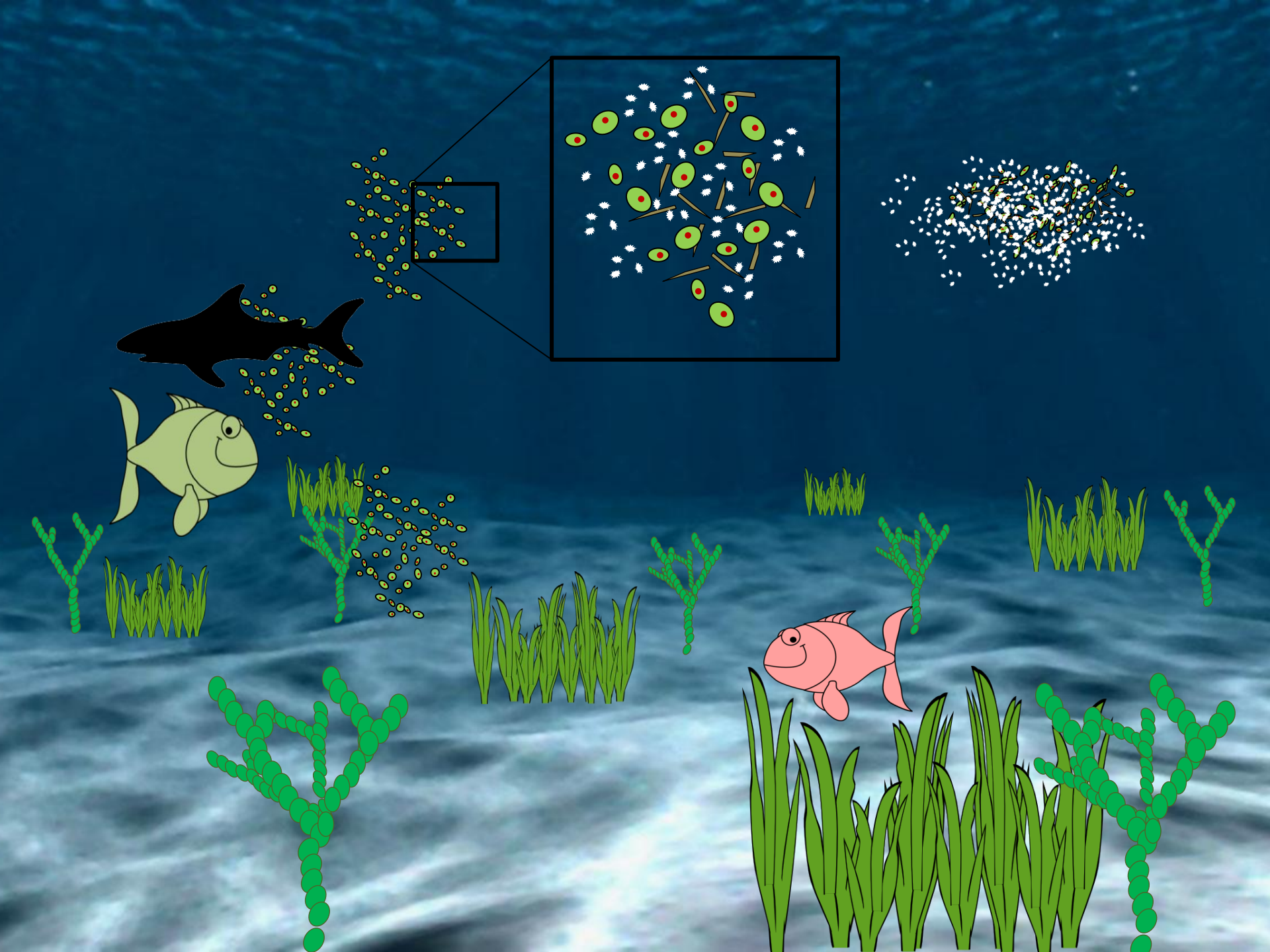


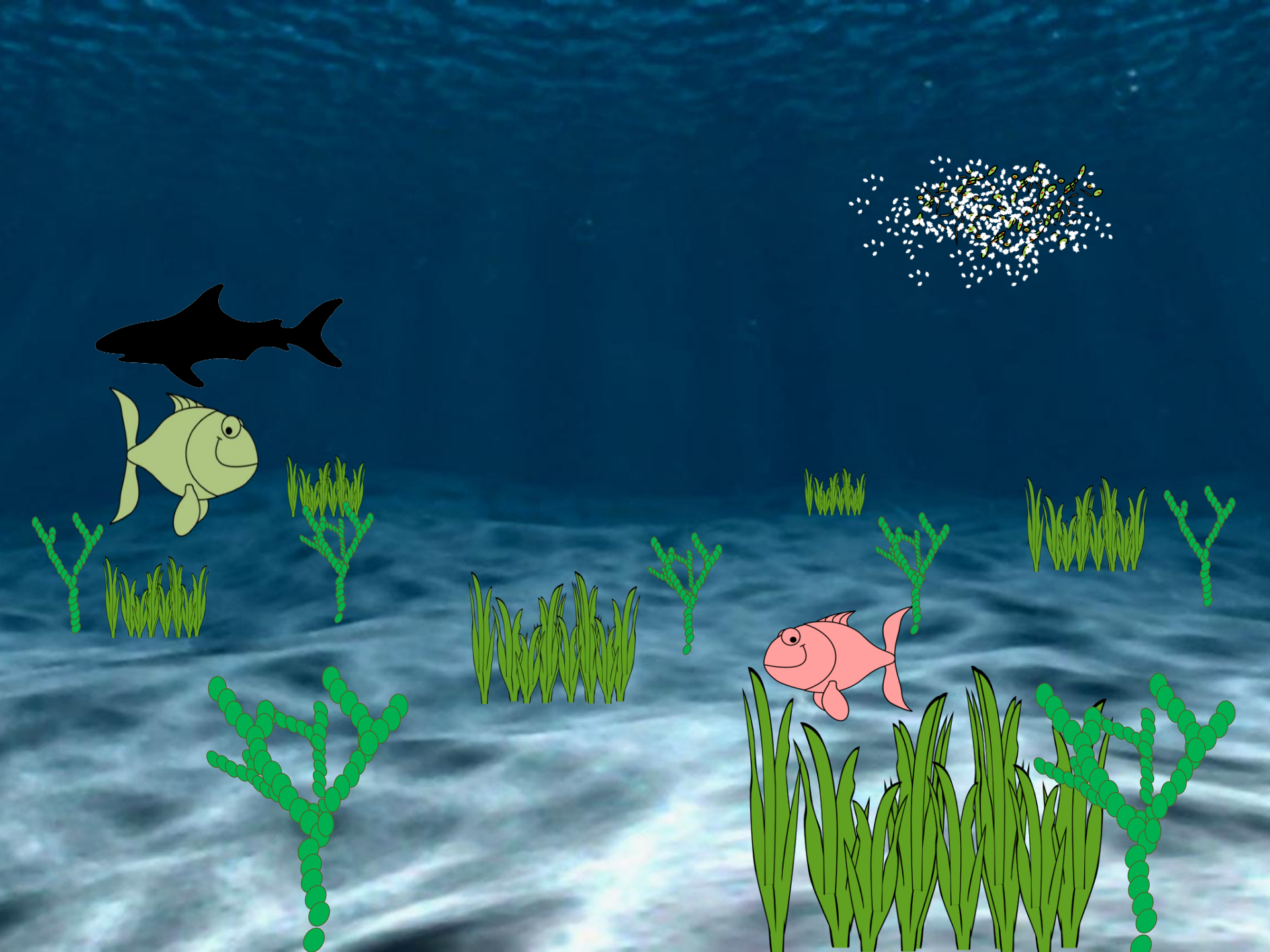


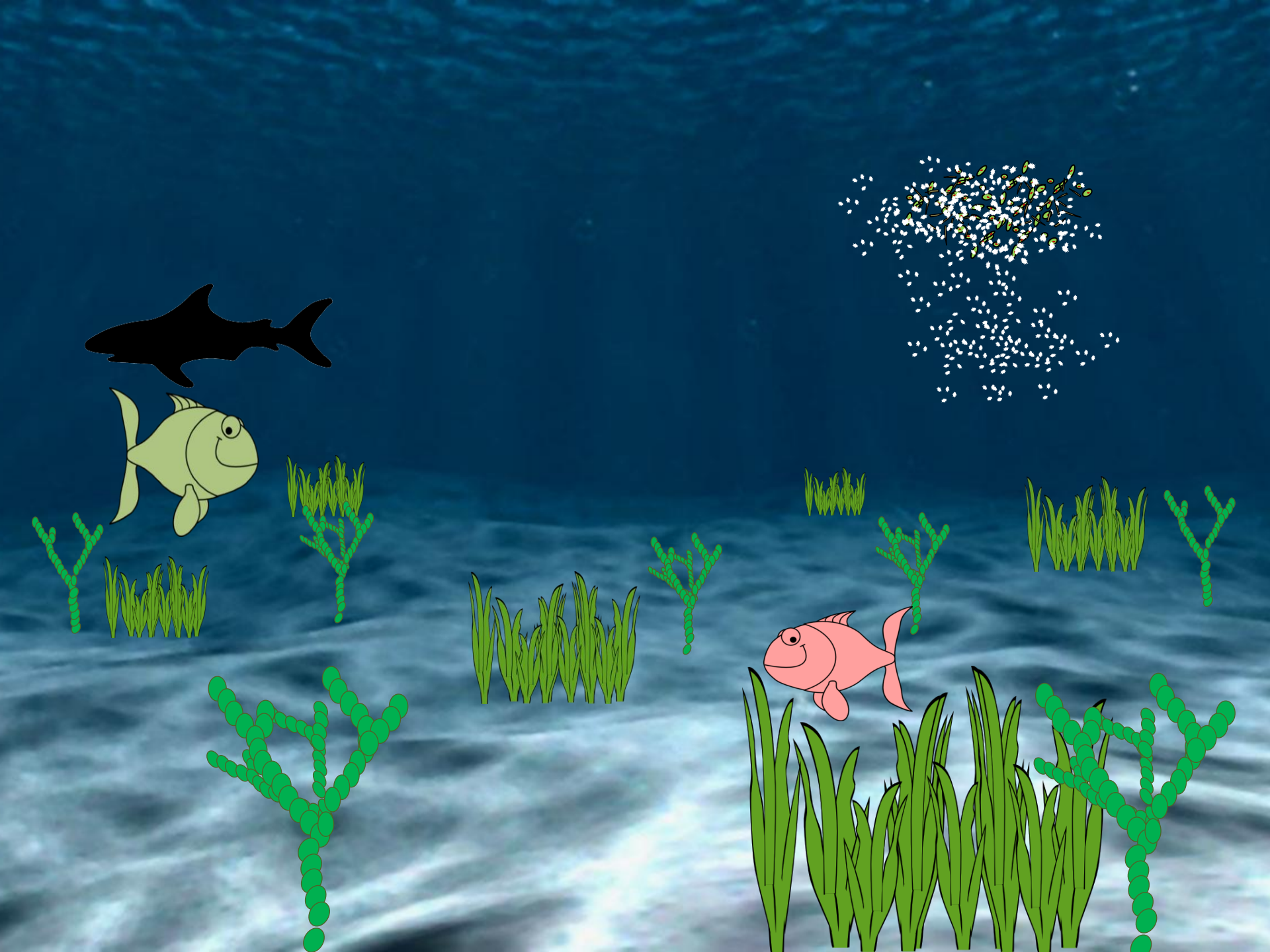

Cyanobacteria
$2CH_2O + 2Fe_2O_3 = 4Fe^{2+} + 2HCO_3 + H_2O$
$2CH_2O + 2NO_3^- = N_2 + 2H_2O + 2HCO_3^-$
$2CH_2O + SO_4^{2-} = H_2S + 2HCO_3^-$
$Fe^{3+} = Fe^{2+} + e$
ANOXIC
PORE WATERS

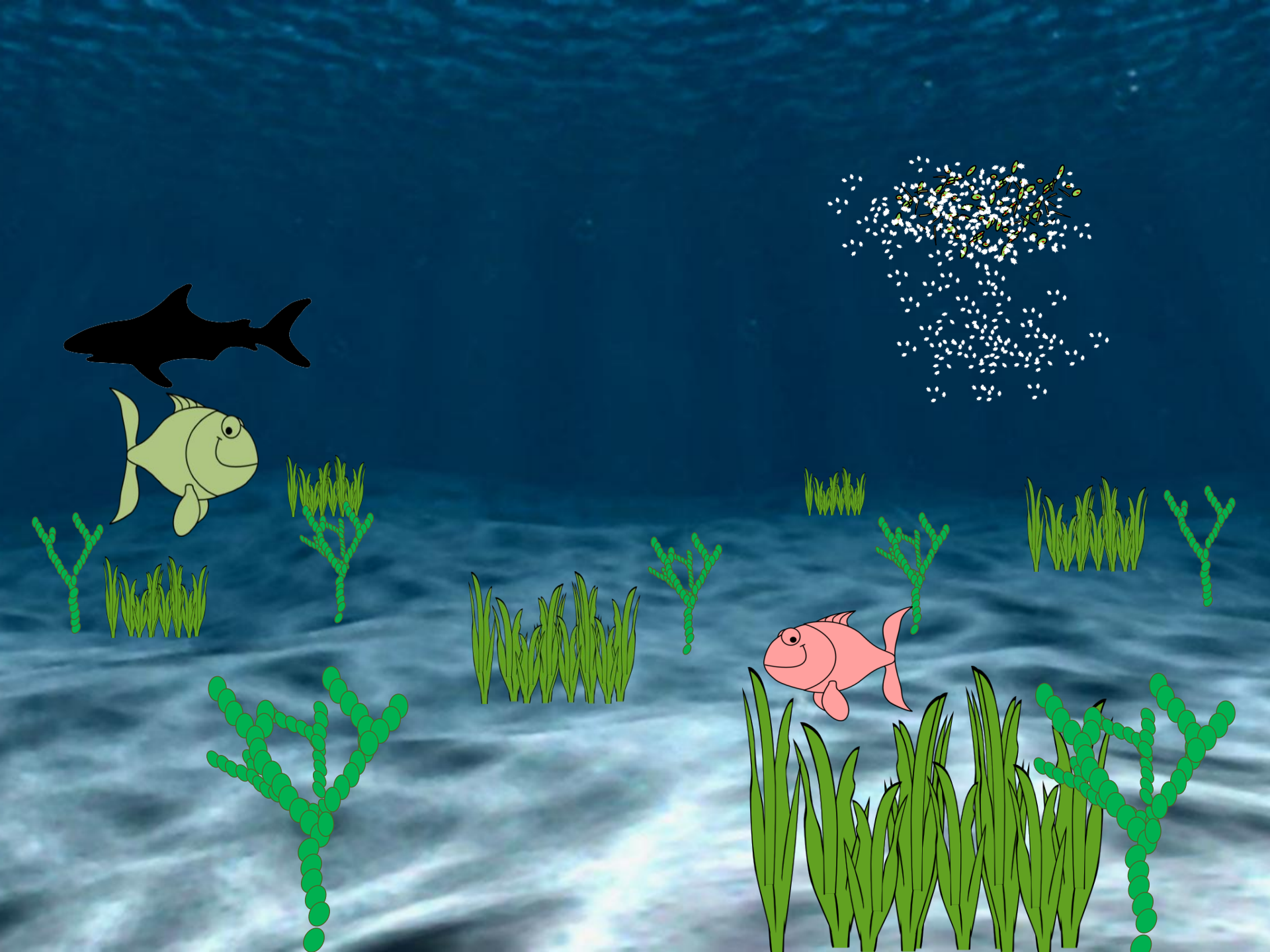

$N_2 = NH_3$
Cyanobacteria
Fe^{2+}
ANOXIC
PORE WATERS

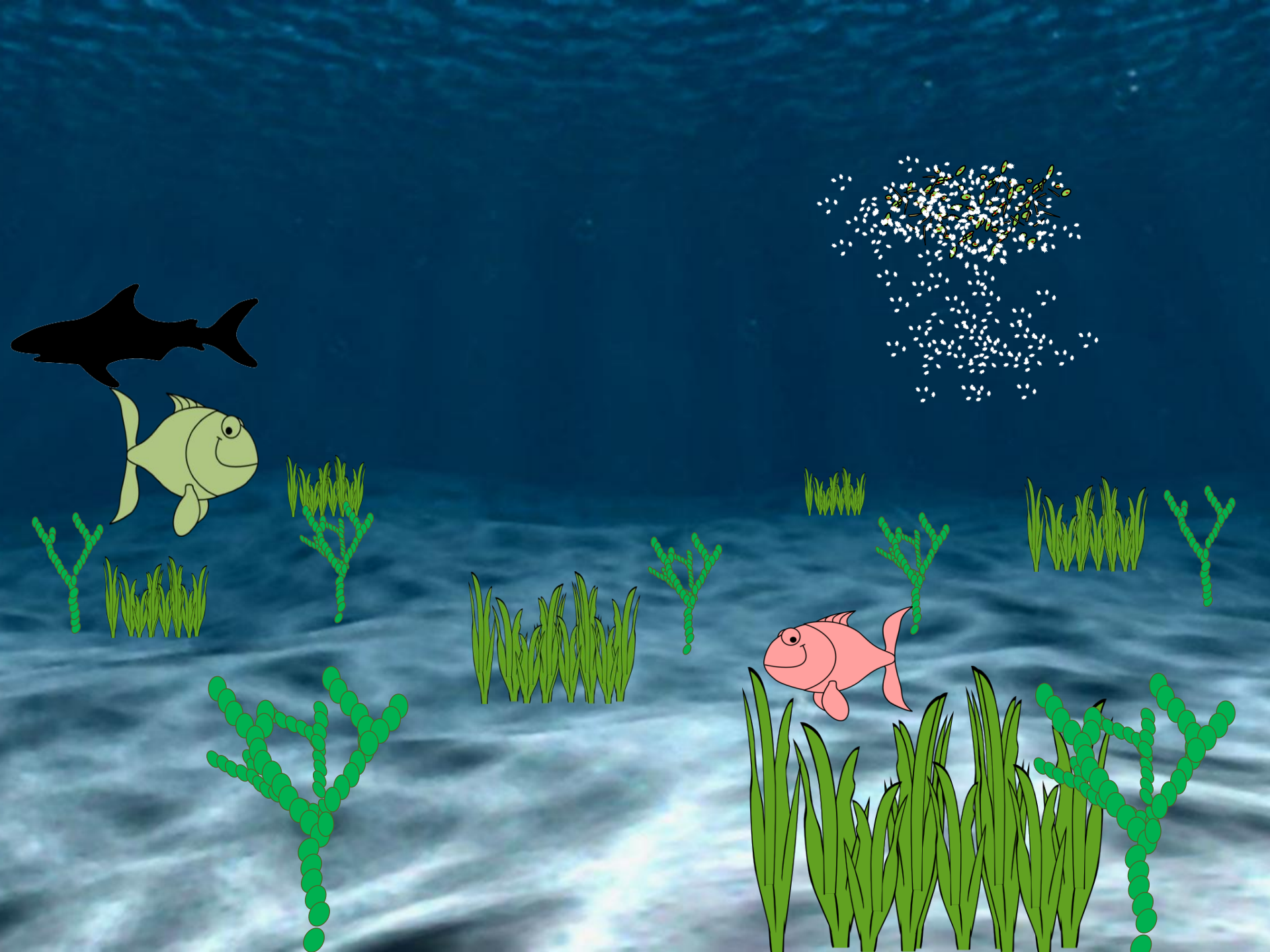

KICK UP OF SEDIMENT AND
FERTILIZED CYANOBACTERIA

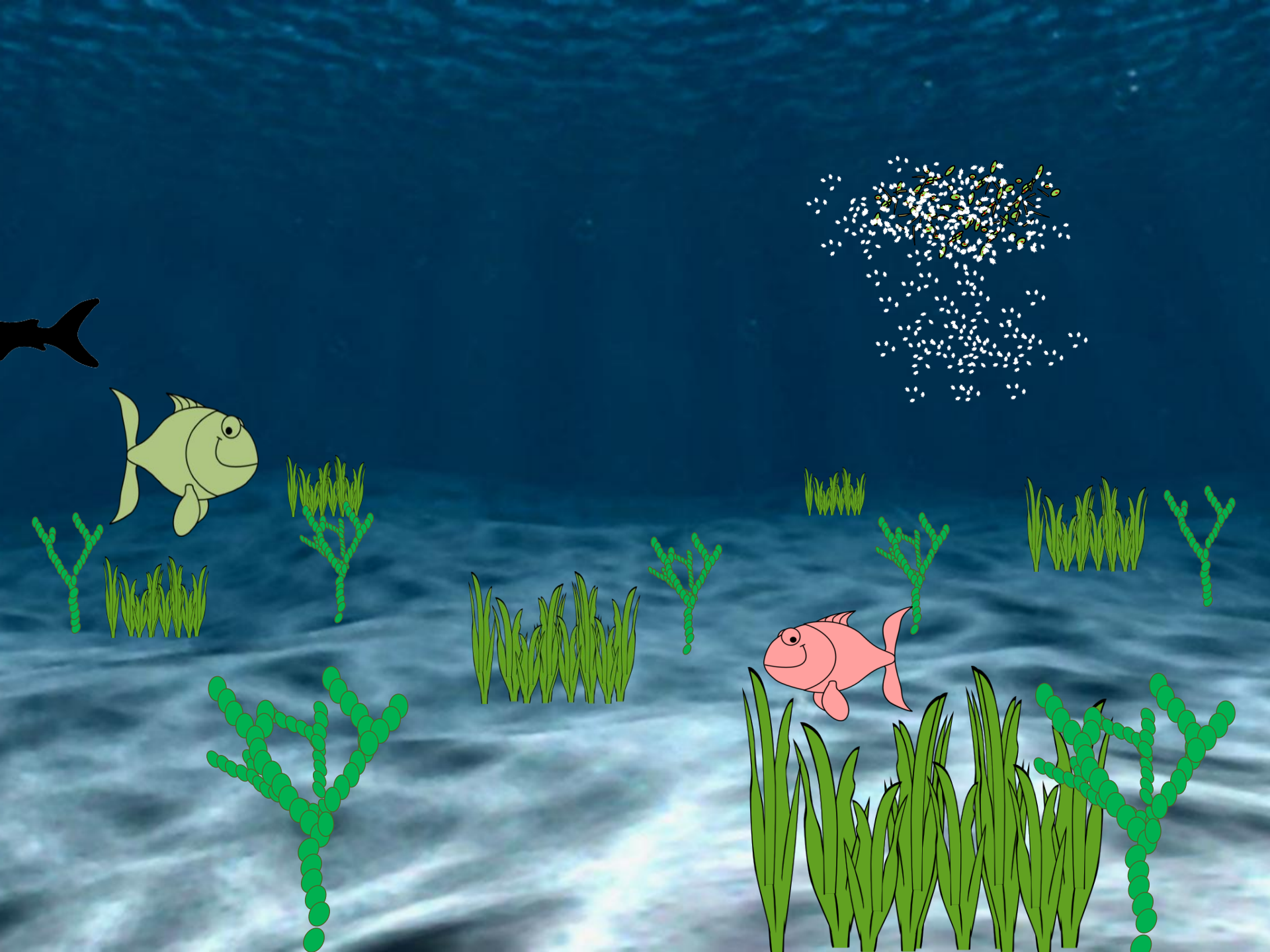


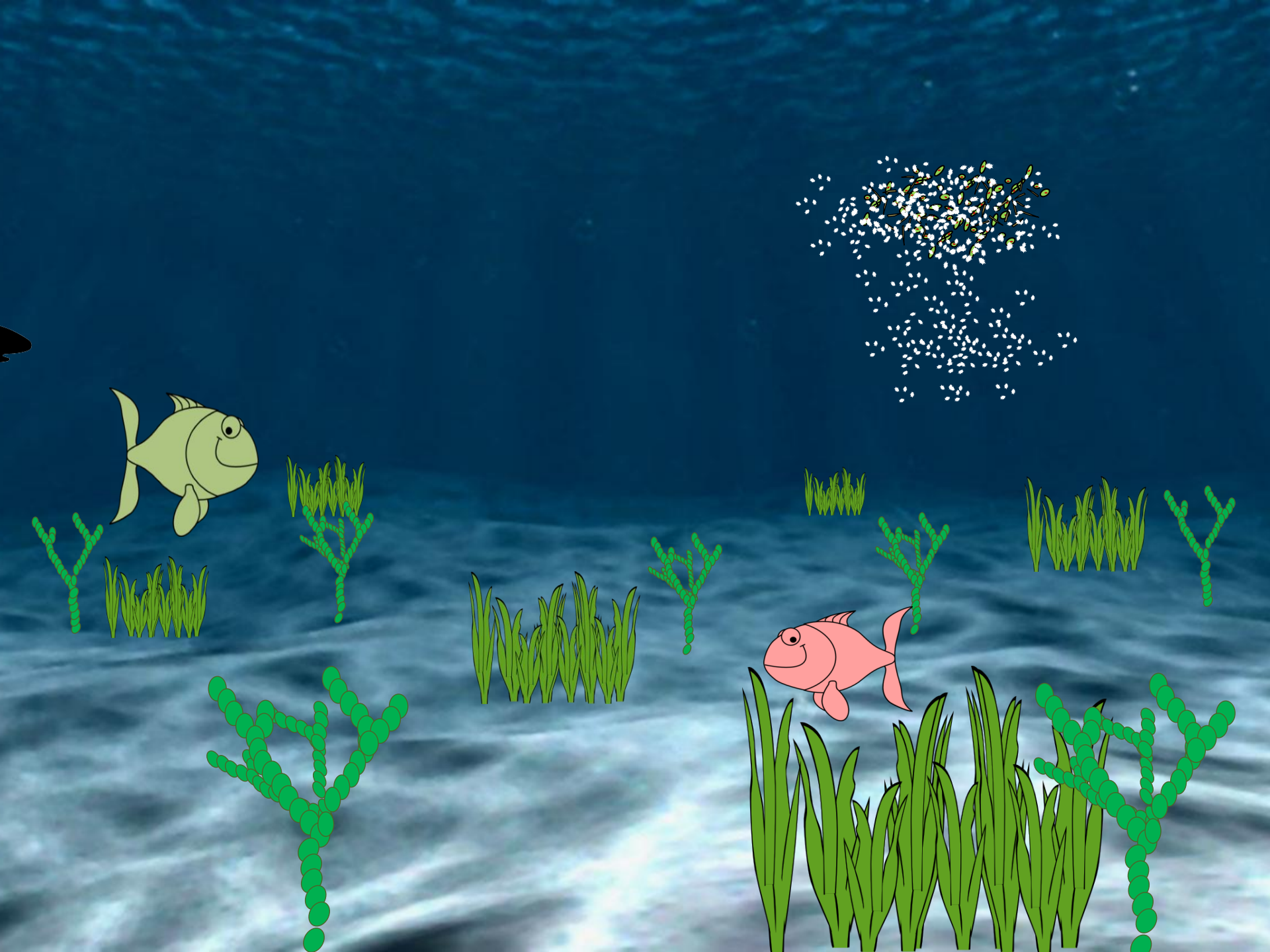


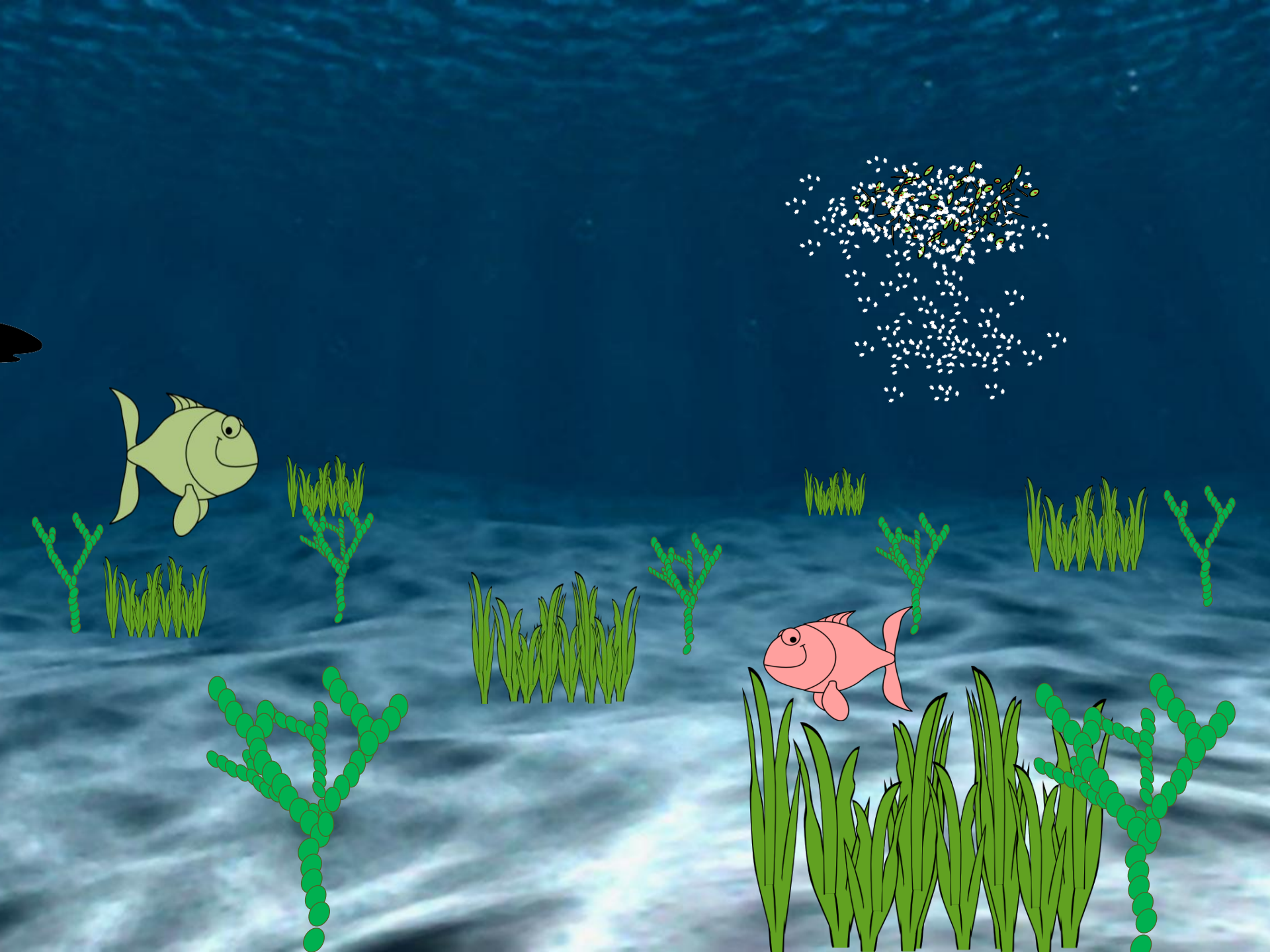


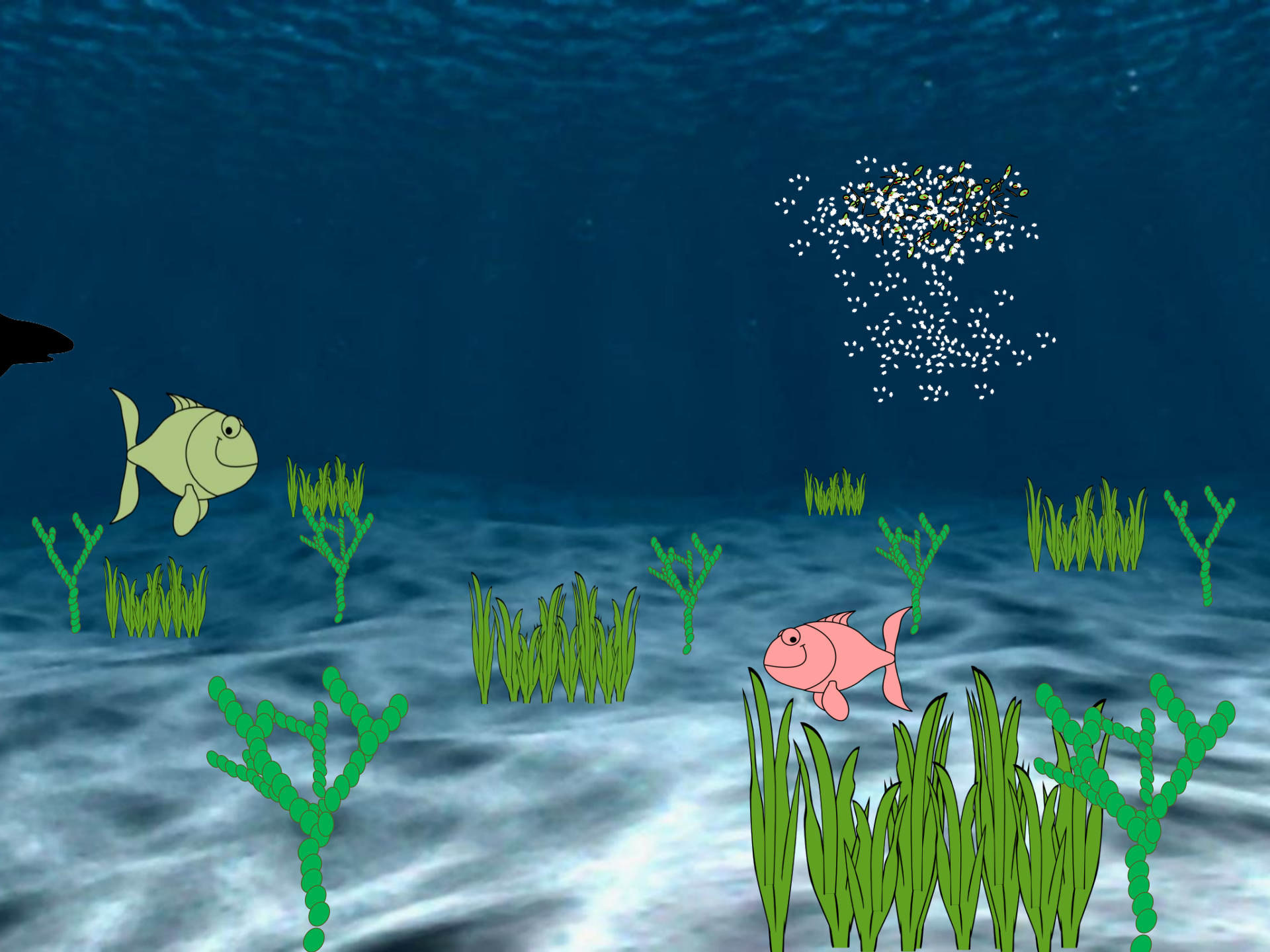


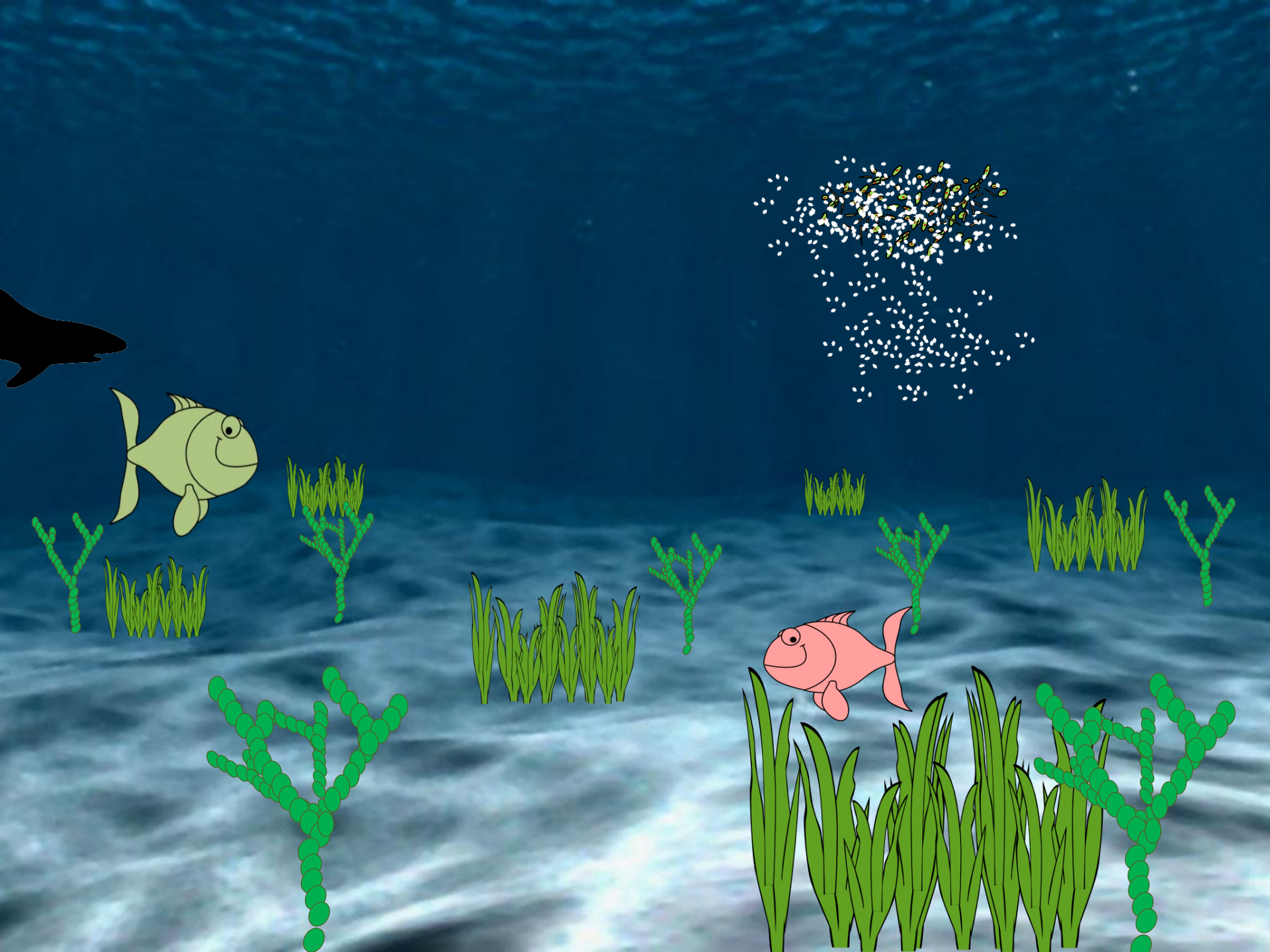


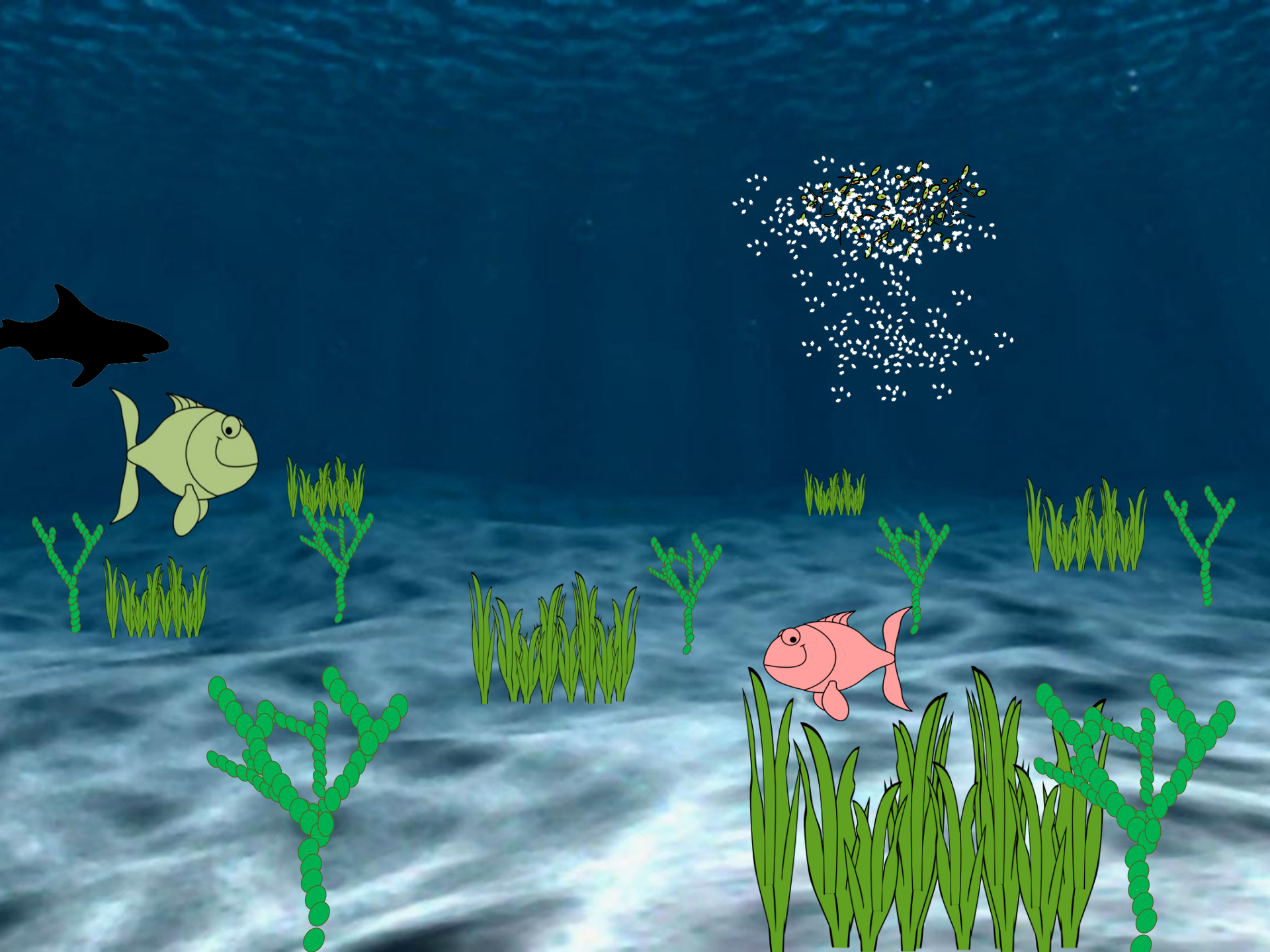


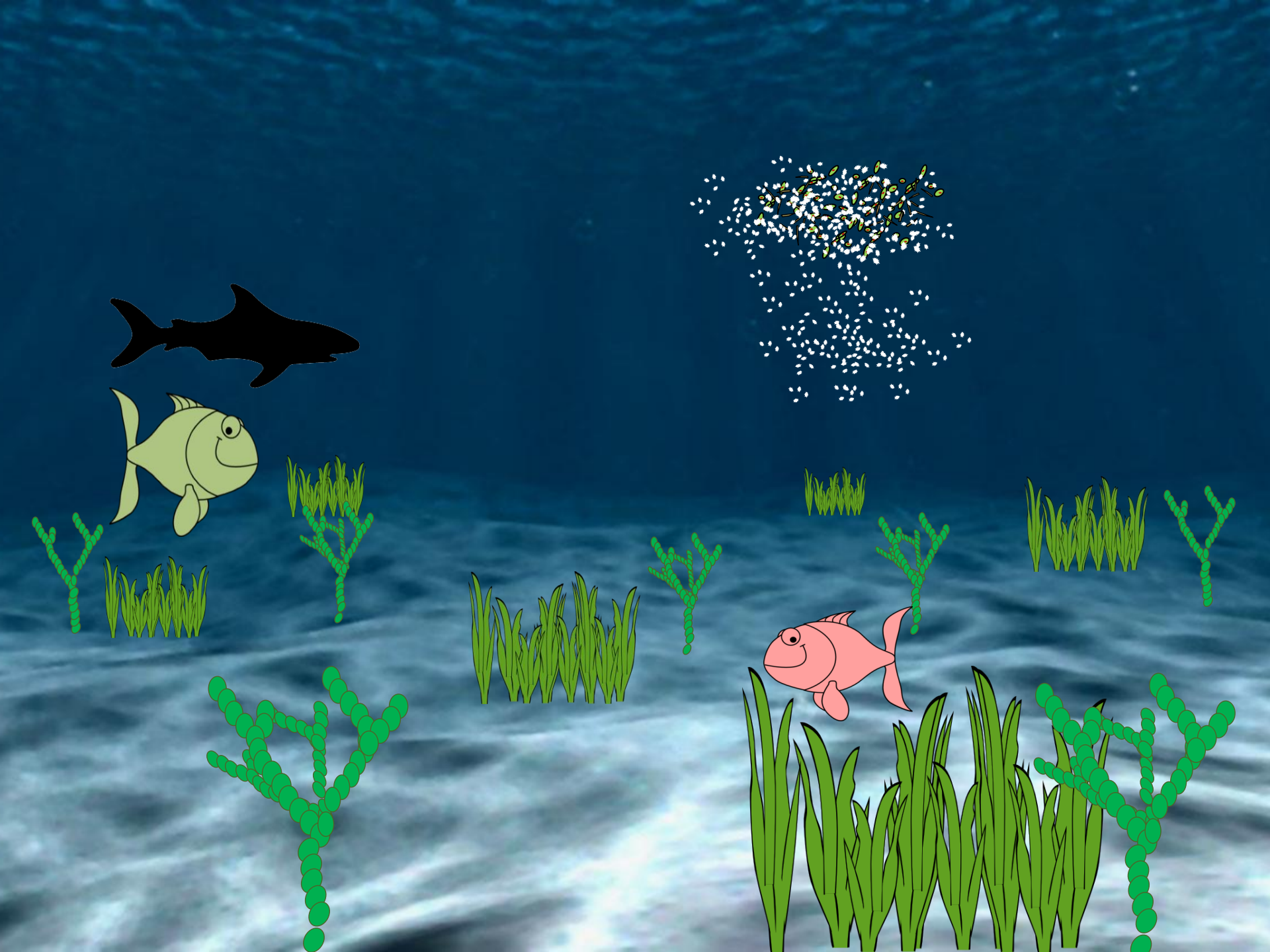


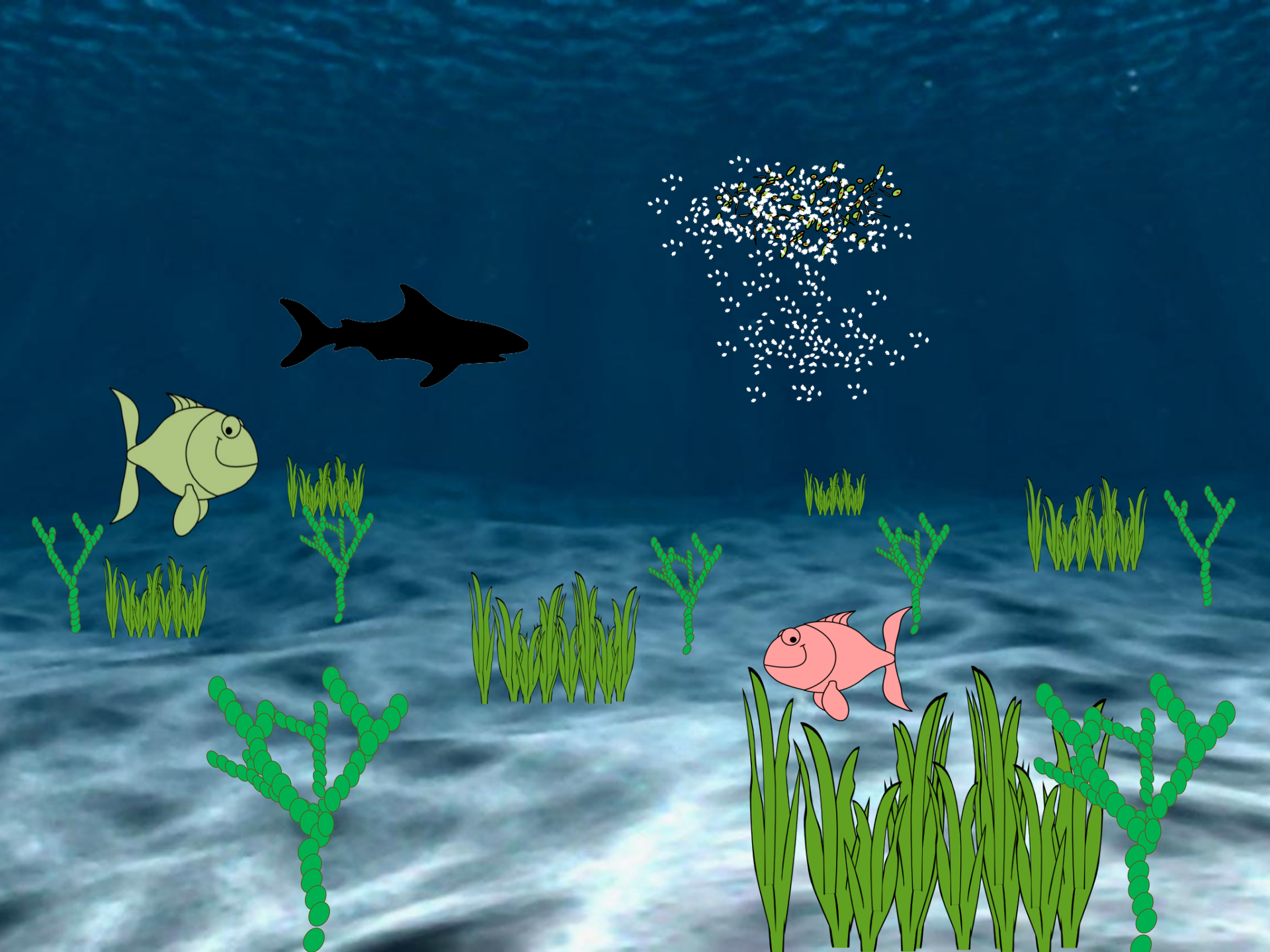


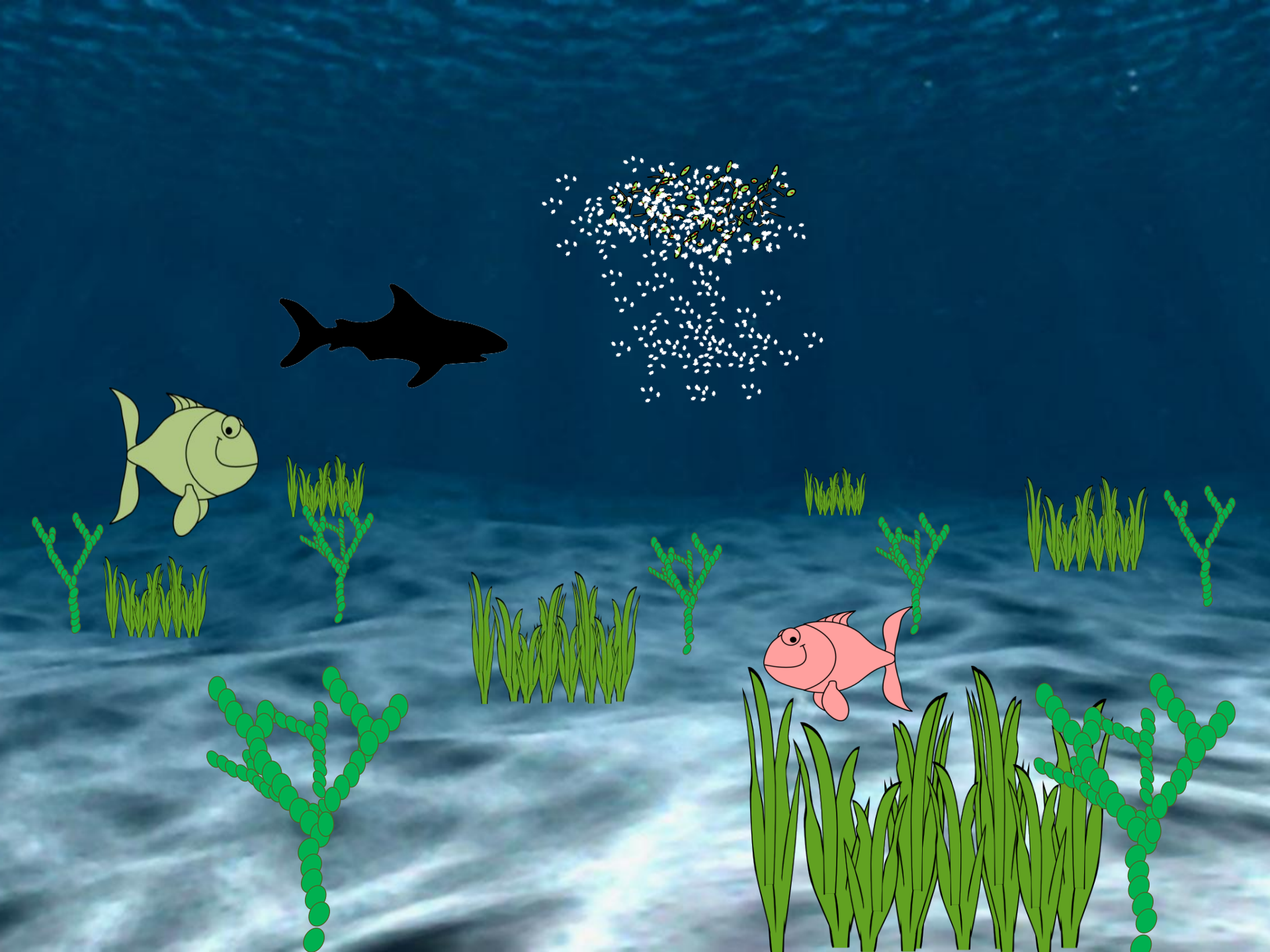


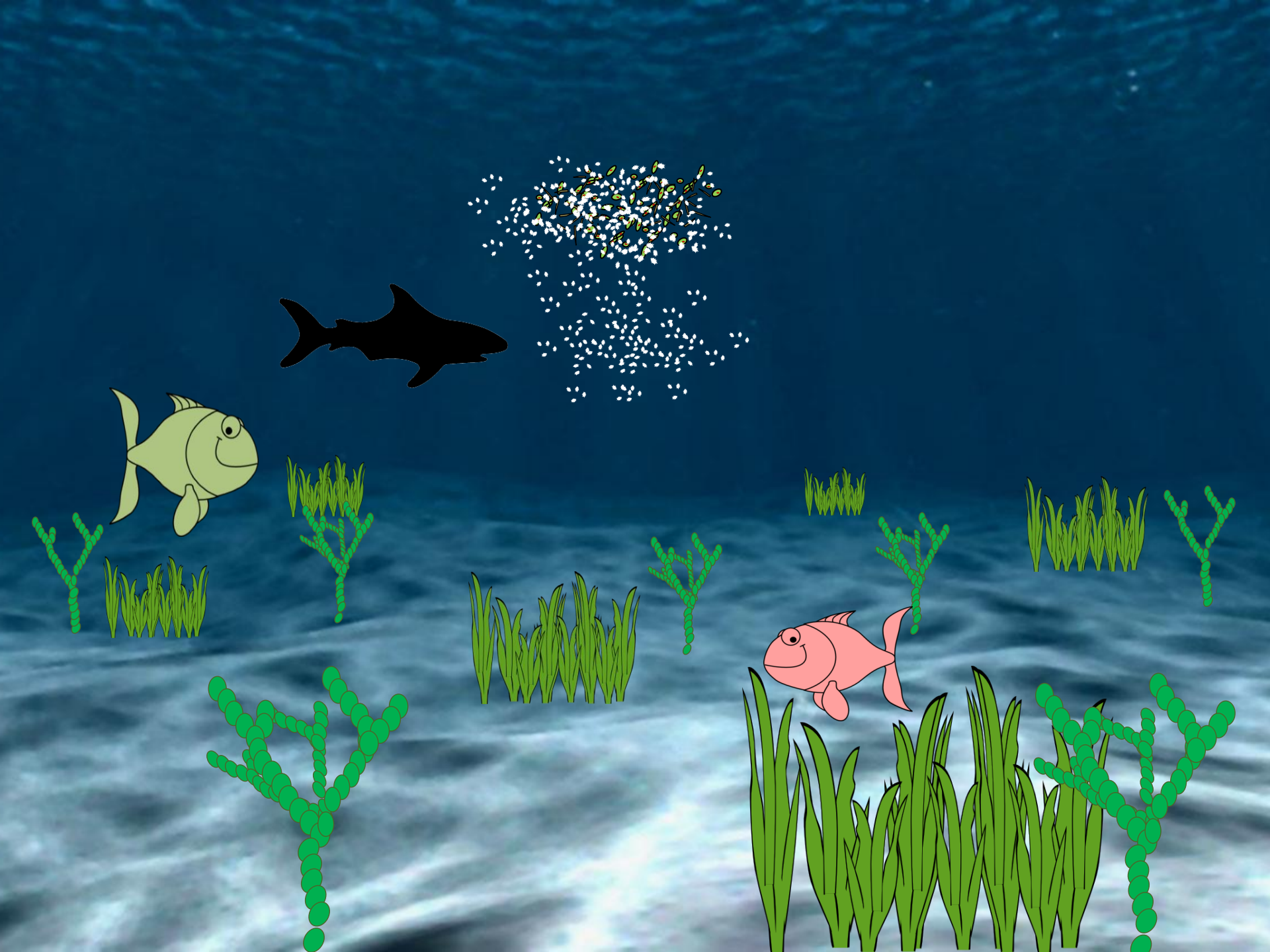


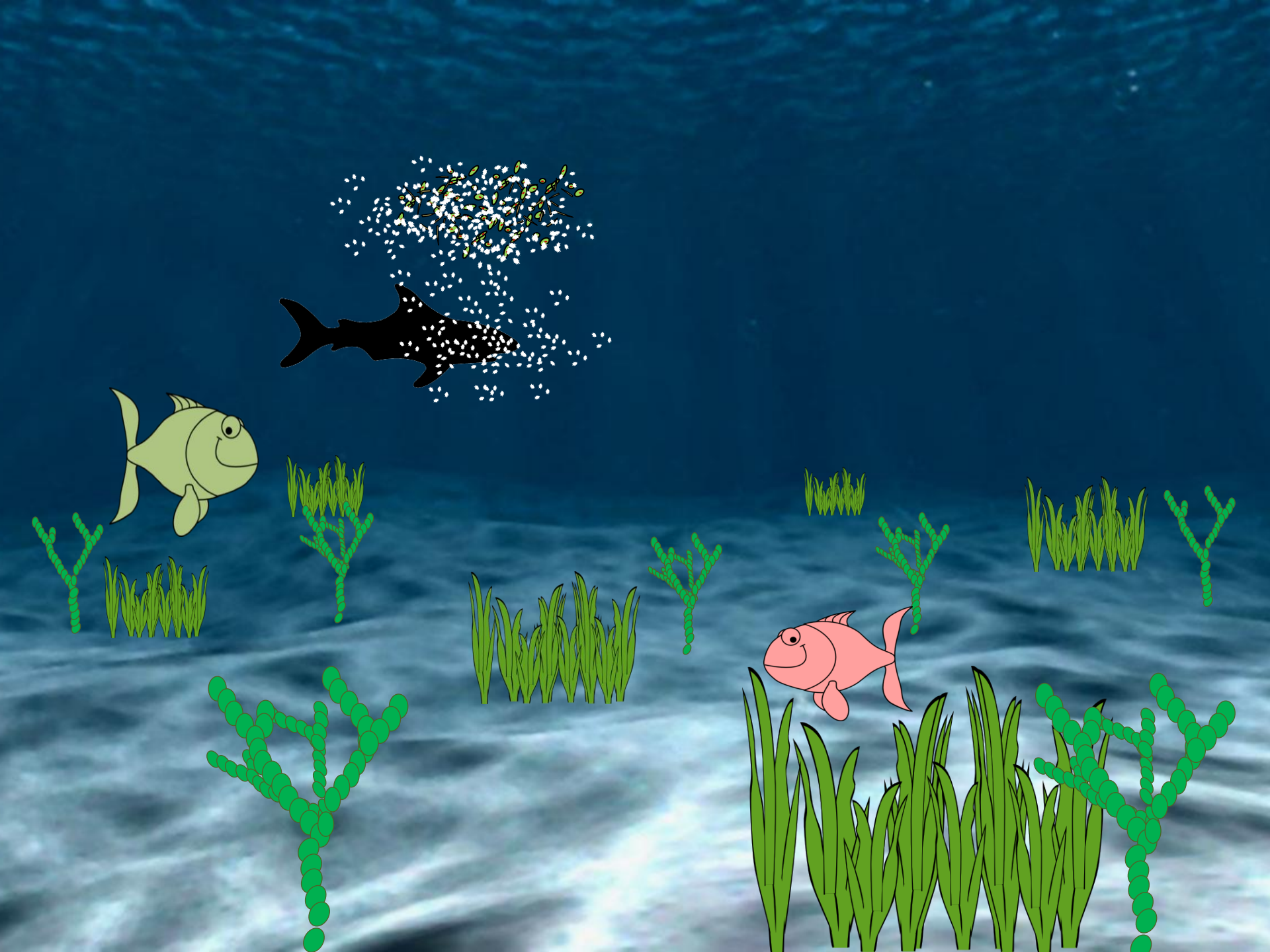


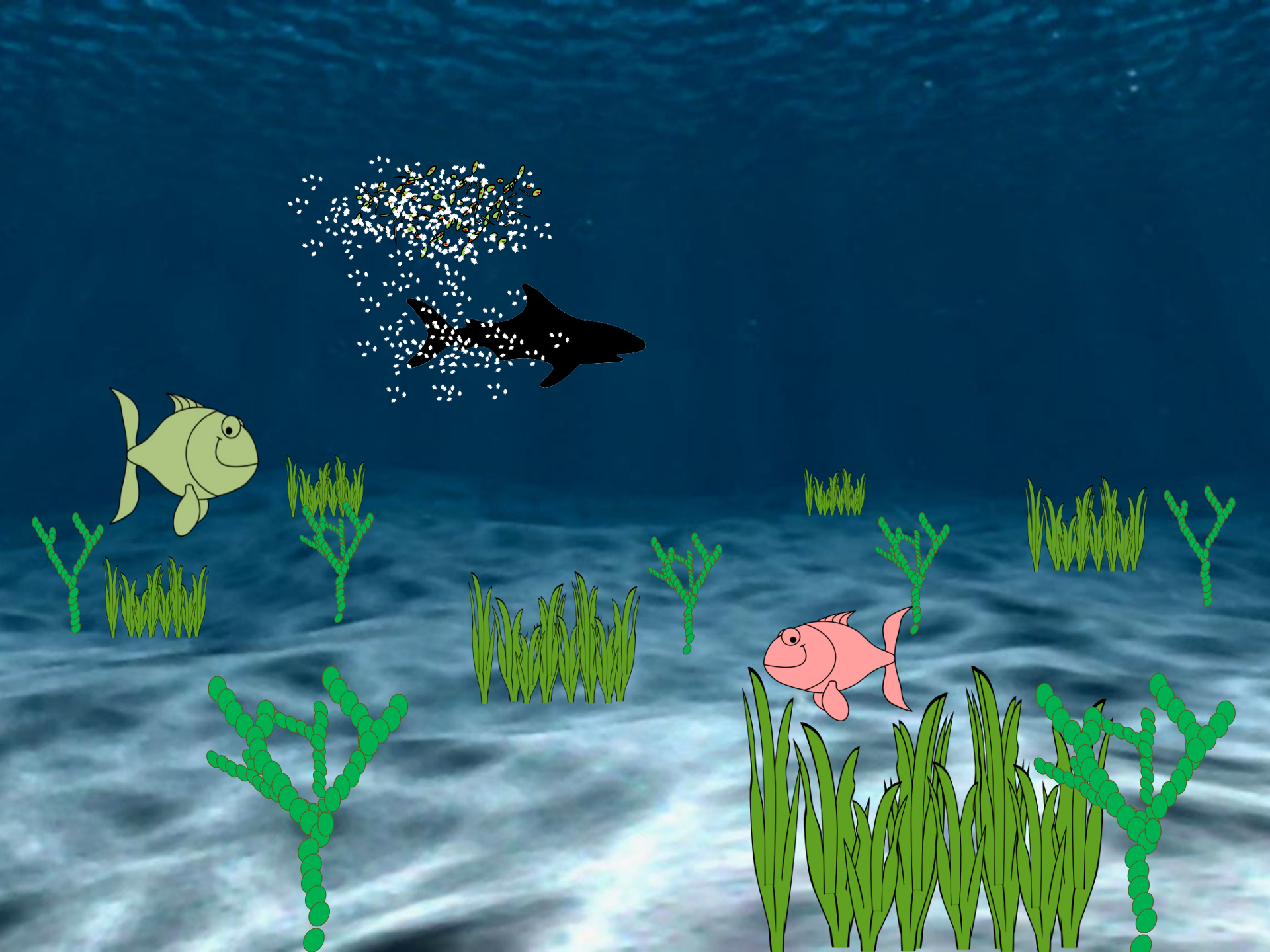


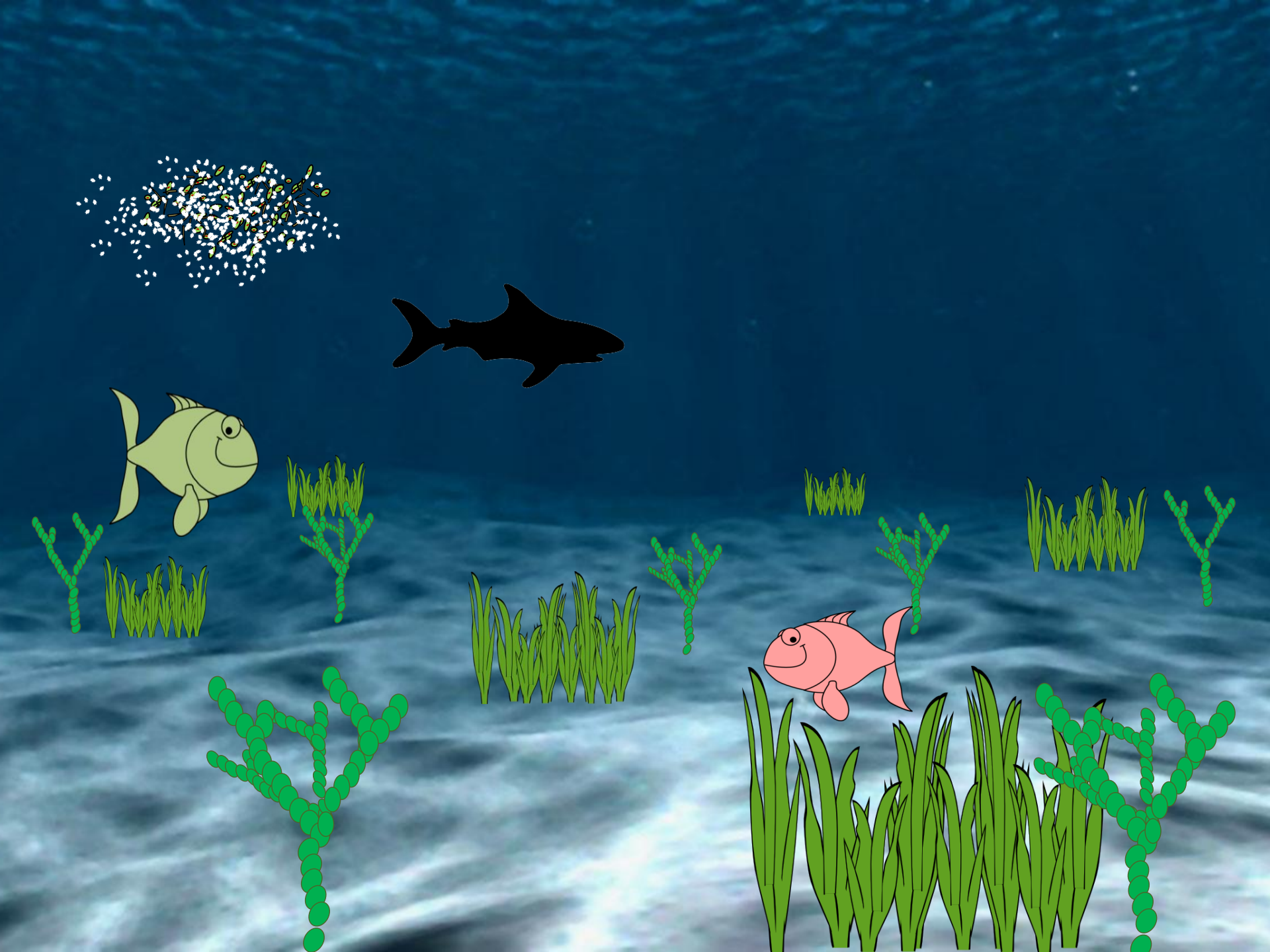


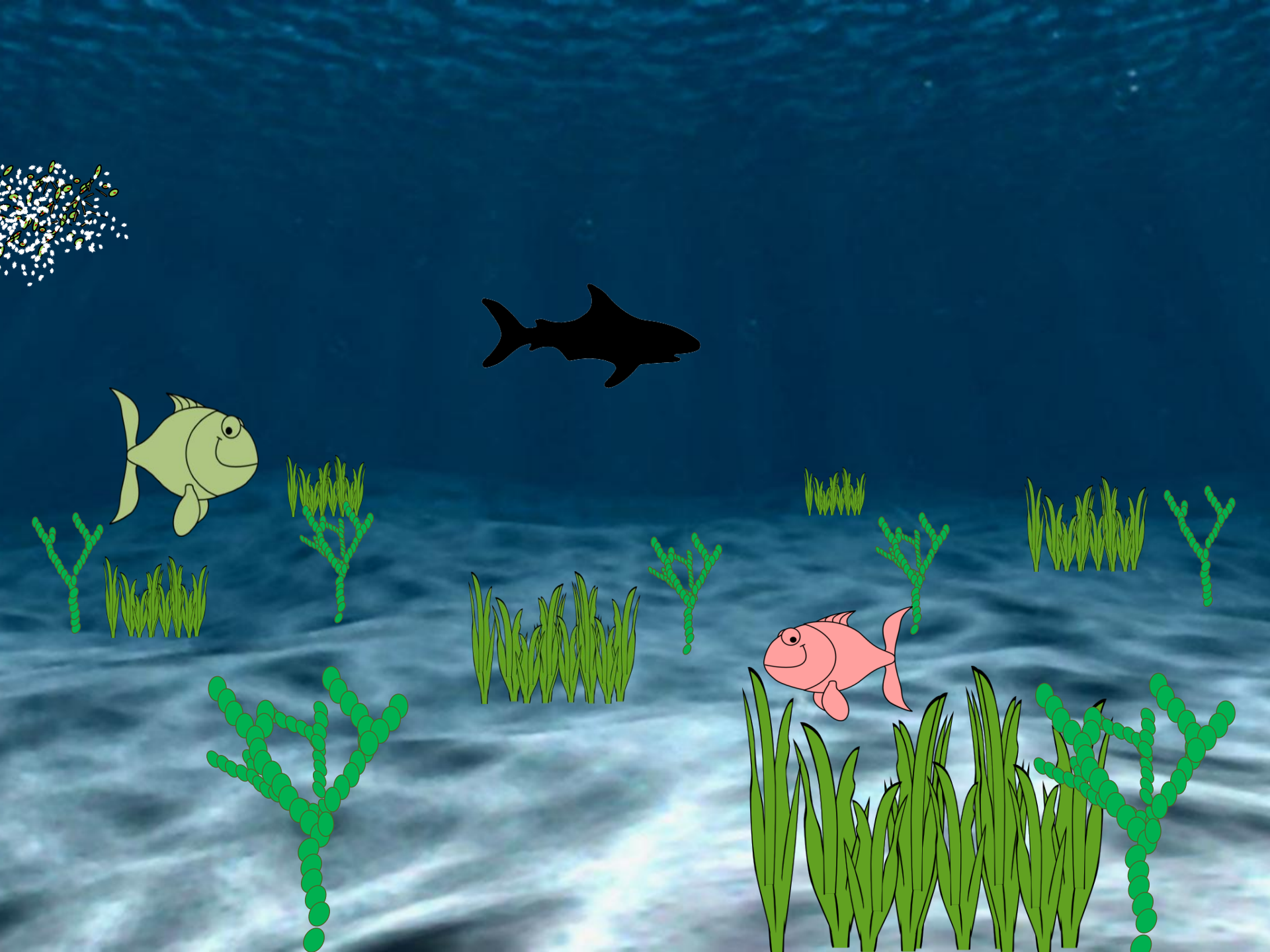


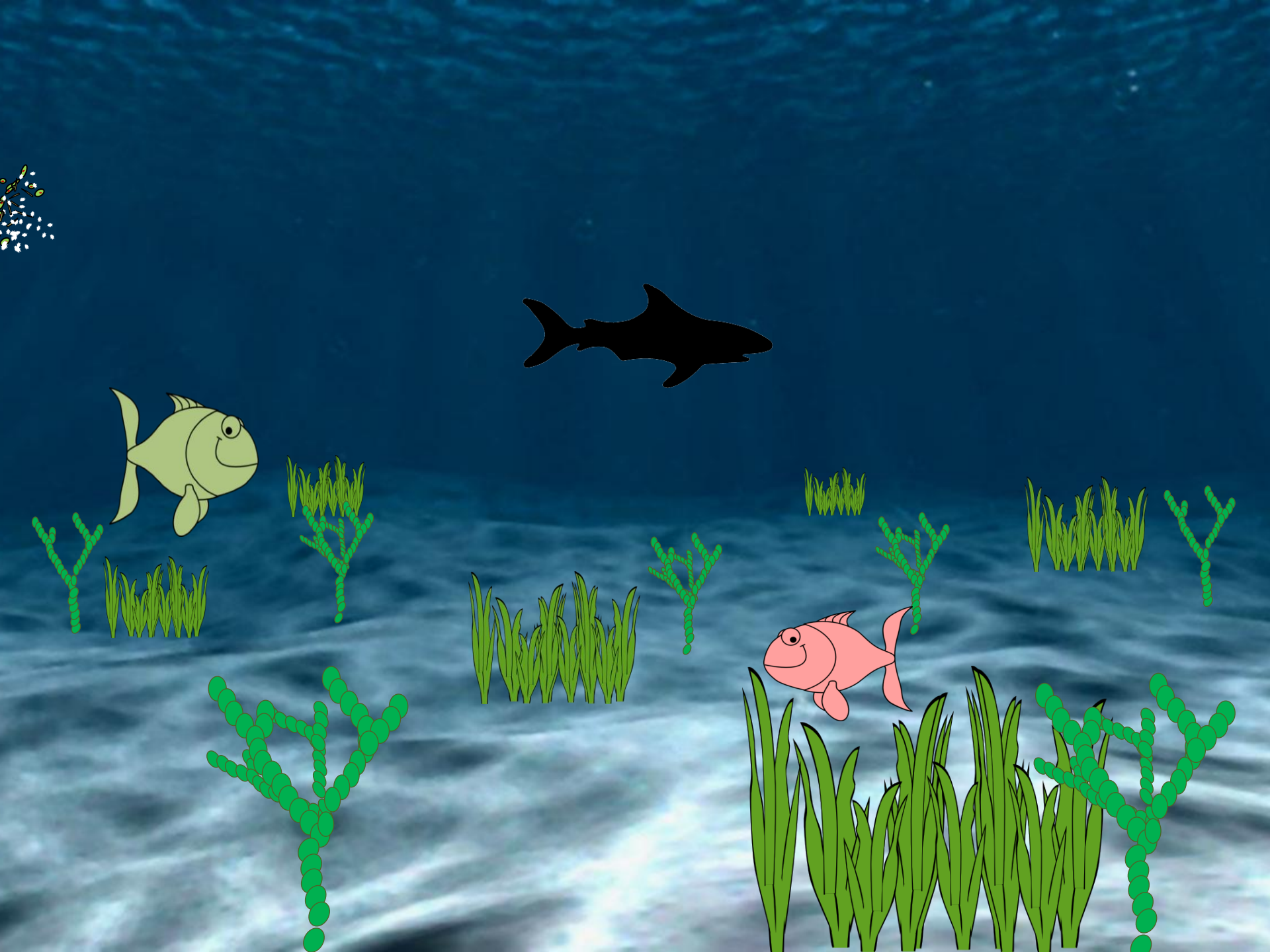


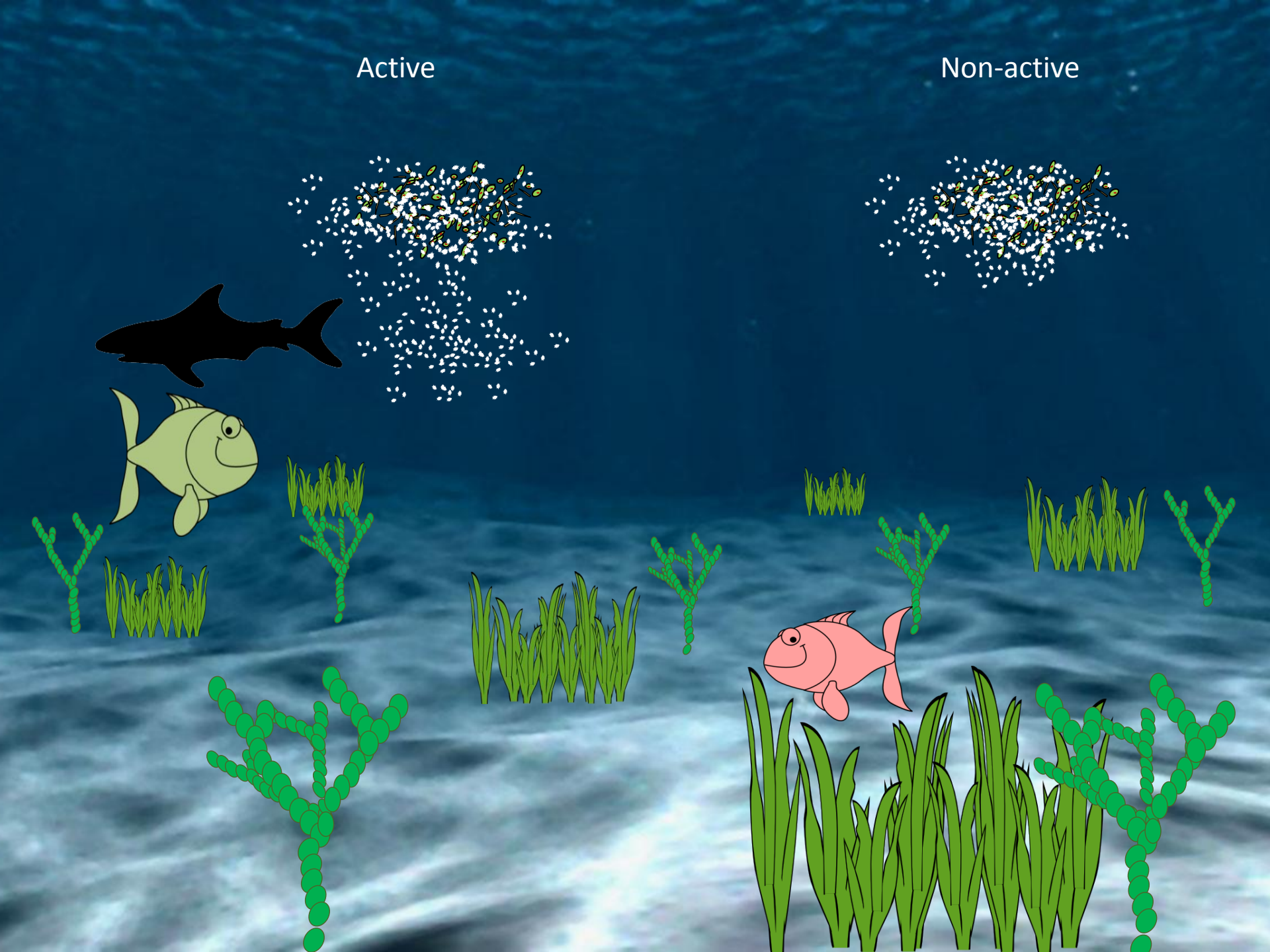











Active
Non-active

Summary

- Dust from Africa provides sources of Fe to the surface sediments of the Bahamas
- The dust contains high concentration of trace elements including Fe
- This stimulates cyanobacterial growth which is in turn instrumental in inducing algal blooms which induce carbonate precipitation
- The fine sediment is swept from the surface of the Bahamas and accumulates on the margins causing platform progradation.

Summary

- Dust direct and indirectly provides N to all the communities on GBB
- Such a mechanism may have been responsible to the formation of carbonate platforms in the past particularly during periods prior to the evolution of calcium secreting organisms

Are nutrients good for Carbonate Platforms?

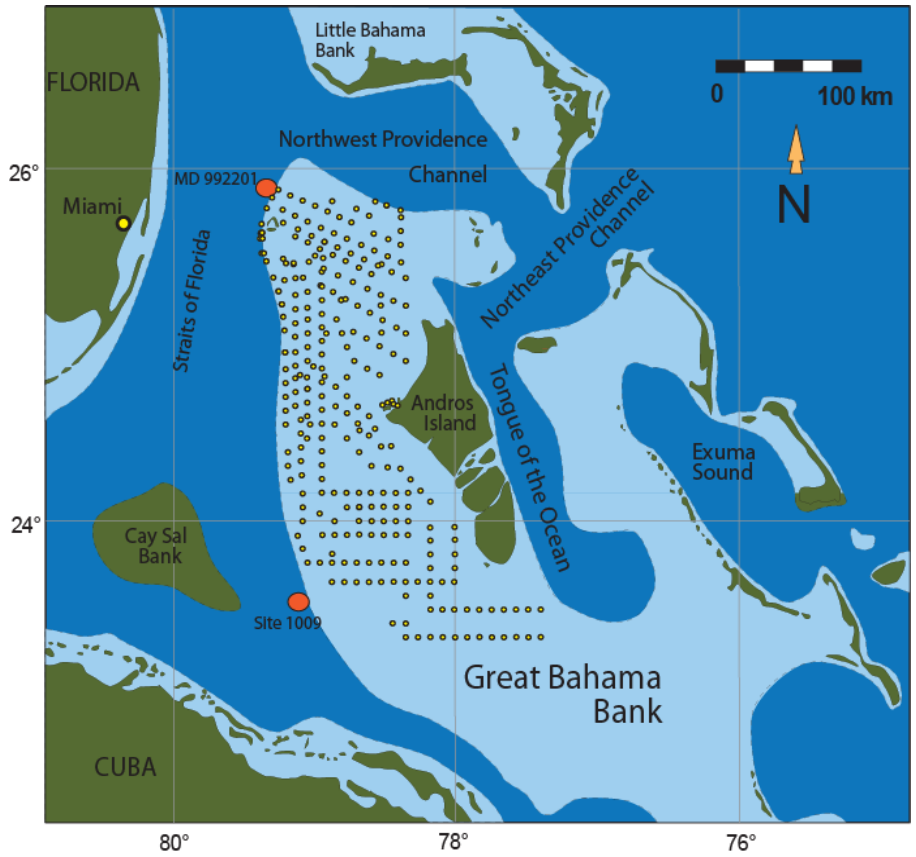
- Hallock, P. and Schlager, W. (1986) Nutrient excess and the demise of coral reefs and carbonate platforms. *Palaios, 1, 389-398.*

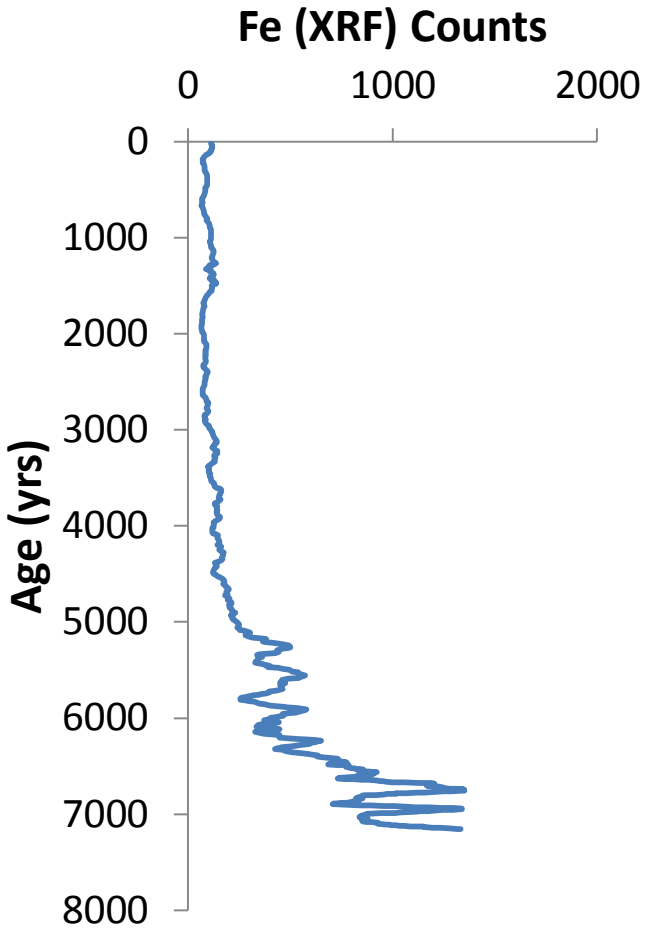
Non-skeletal dominated carbonate platforms such as the Bahamas are positively stimulated by a modest input of nutrients.

In Contrast
Excess nutrients cause excess fleshy algal growth and lead to the deterioration of skeletal dominated carbonate platforms.

What is Next?

- Test the Various Hypotheses
  - Use genetic tracers to identify N-fixing and Fe-reducing bacteria in whitings and sediments
  - Use more sophisticated geochemical tracers
- Examine the porewater geochemistry to trace Fe
- Prepare a N budget for GBB
- Examine the geological record of Fe and N isotopes in cores





Roth, S. and Reijmer, J.J.G. (2005) Holocene millennial to centennial carbonate cyclicity recorded in slope sediments of the Great Bahama Bank and its climatic implications. *Sedimentology, 52, 161-181.*

What is Next?

Cores